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Weights of Evidence Predictive Modelling in Archaeology

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ABSTRACT
For predictive archaeological modelling to be effective it requires an understanding of how environmental and anthropogenic spatial phenomena influence the selection of archaeological site location in the past and how researcher biases influence raw data collection and analysis and use in these models the present. This paper aims to demonstrate the utility of the weights of evidence method (WoE) for predictive modelling using the ArcSDM toolkit in ArcGIS for predicting Bronze Age settlement patterning in two river valleys in Cyprus. The WoE method is a probability-based procedure for determining the archaeological potential of a region using the spatial distribution of spatial phenomena with respect to known archaeological site locations. *Weights* (W+, W−) and *contrast* (C=(W+)−(W−)) calculations underpin the data-driven procedure. As data, this method uses sites identified under methodologically distinct ground surveys and employs six "evidential layers" that reflect natural and anthropogenic spatial phenomena (hydrogeology, rivers, vegetation, landuse, soil and slope) believed to influence site selection in the past to produce predictor maps for the study region. The predictor maps aim to demonstrate spatial patterning of archaeological settlement over time (the Bronze Age) and inform current theoretical debate over the nature and spatial patterning of socioeconomic activity that unfolded over the course of the Bronze Age. Th predictor maps may also prove useful for informing land development policy by identifying archaeological sensitive areas that should receive due care. The analysis of these relationships using GIS and weights of evidence modelling identified 51km^2 of archaeologically favorable landscape that can be organised into 26 specific locations within 8 sub-regions and a foundation for guidance that led to a successful ground survey in a previously unsurveyed region of the study are that led to finds spanning the Chalcolithic to modern era.

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ACRONYMS

Acronym	Full Title
ACCI	Agterberg-Cheng Conditional Independence
AOI	Area of Interest
AoAP	Area of Archaeological Potential
ArcSDM	Arc Geographical Information System Spatial Data Modeler
BA	Bronze Age
BP	Before Present
CAPP	Cumulative area-posterior probability curve
CI	Conditional Independence
EBA	Early Bronze Age
GIS	Geographical Information System
GPS	Geographical Positioning System
KGS	Kvamme's Gain Statistic
LBA	Late Bronze Age
MBA	Middle Bronze Age
MVASP	Maroni Valley Archaeological Survey Project
VVP	Vasilikos Valley Project
WoE	Weights of Evidence

1 Introduction

1.1 Overview

This study details the development of predictive models to understand and preserve the archaeological landscape of the neighbouring Vasilikos and Ayios Minas valleys of south-central Cyprus. Archaeological predictive modelling maintains that spatial phenomena – archaeological sites – are limited in distribution and that their occurrences are not random nor uniform but influenced and constrained by climatological, geological, anthropogenic, and other environmental spatial phenomena. Understanding the relationship between these phenomena and archaeological settlement can produce maps detailing areas of archaeological potential (AoAP) that may contain yet unrecorded sites. Reducing a region to a series of AoAP is an economical, efficient, and robust means of exploring an archaeological landscape.

Not all methods of predictive modelling are equal in their rigour and effectiveness and there exists an extensive history of trial, error and development that had varying degrees of success in handling value-weighting of contributing factors, bias in datasets and the inherent uncertainty in predictive models (Verhagen 2007). In this study, the Weights of Evidence (WoE) method is used to investigate the archaeological potential of the study area as it most effectively engages these general challenges but also has in-built methods of limiting the effects of the bias introduced by the ground surveys' distinct methodologies of data capture. Usefully, the WoE method is accompanied by a large body of research detailing its benefits and drawbacks across many disciplines including geology, medicine, finance, and archaeology and it's process has been incorporated into a powerful ArcGIS toolkit called Arc Spatial Data Modeler (ArcSDM). ArcSDM streamlines the process of modelling and offers clear and concise results as output tables and maps without obscuring its methods to the modeller. The approach taken in this study is geology-centric as it takes its lead from the majority of research in this area that argues that settlement patterning is heavily influenced by the underlying geology and its constituent soils. As these claims have not been evaluated from a mathematical perspective, this predictive model aims to put them to the test in a novel way.

This model adopts the common method of organising Mediterranean valleys into three zones including the uplands (mountains proper), midlands (foothills of the mountains) and lowlands (coastal flatlands and coast). Archaeological ground-truth survey in the study area has focused on the midlands and lowlands. The Vasilikos Valley Project (VVP) (Todd 2004; 2013), an extensive and rural-oriented ground survey focused on the lowlands and midlands of the Vasilikos valley while the Maroni Valley Archaeological Research Project (MVASP) (Manning et al. 1994; 2000; 2002; 2014), that employed an intensive rural-oriented ground-based survey, focused on the lowlands of the Ayios Minas valley (often referred to as the Maroni valley after its largest settlement). As will be discussed below, the geographic and geological blindspots of each survey methodology are addressed by combining their datasets within the WoE method. Historically, and in the case of these surveys, it is the Bronze Age (BA) between 2400-1100 calibrated years before present (Cal BP) that has been the focus of research in the region (Todd 2004; 2013; Manning et al. 1994; 2000; 2002; 2014). As a result of this bias, and particularly because it is believed that factors influencing site selection changed over the course of the BA, this study will produce three models, one concerning sites dates to the early BA, another considering sites of the middle BA and a third that merges all sites to reveal the general archaeological character of the two-valley region across the entire BA.

As such, the BA has been understood to be a time of transition from millennia-old household-oriented agro-pastoral subsistence farming focused on growing crops and raising livestock to an economy heavily invested in capital-intensive (high-input for high-financial gain) goods such as copper and olives for export into international markets (Knapp 2013). This socioeconomic development created changes in settlement patterning over time observed in the changing positions of recorded settlements and cemeteries and the AoAP identified by the predictive models developed below. By the late BA in some areas of Cyprus there is evidence for well-developed centralised settlement hierarchies based on social stratification, central control of resources, industrial levels of production and the control of exchange networks by elite groups (Knapp 2013: 353-54). These patterns are less clear in other areas of the island due to a lack of excavation or perhaps because they were only just emerging or even had failed to develop. Material culture from confirmed settlements suggests that the crucial shift in settlement patterning occurred between the earlier and later stages of the middle BA. A single predictive model would obscure this important transition and so, as mentioned, two models, one based on sites dating to the early BA and earlier middle BA and a third based on sites dating to the later middle BA and late BA are developed.

This study has four main aims.

1) Demonstrate the utility of the WoE method for predictive modeling based on its ability to minimize the effects of uncertainty and bias. Specifically:

    a) FOUR areas of bias general to predictive models (uncertainty, precision, accuracy and value placed on importance of landscape characteristics) and;

    b) THREE areas of bias unique to the study area (the chronological focus on the BA, the spatial resolution differences in survey methodology-extensive/rural-oriented vs intensive urban-oriented; and the distinct regional foci in surveys-lowlands/midlands vs lowlands).

2) Develop a model that predicts AoAP for archaeological sites, regardless of chronological affiliation, to guide future archaeological survey toward general site identification and to limit archaeological destruction by developers by highlighting at risk areas.

3) Develop two additional models that predict AoAP for

    a) the early BA/earlier middle BA and;

    b) the later middle BA/late BA

    to test current theory that associates diachronic settlement patterning to socioeconomic development. Specifically:

    i. Where else might early, middle and late BA sites be found in the study region?

    ii. In what areas might early (early BA to early Mid BA) evidence for local proto-tiered/hierarchical system be found?

    iii. Does the expanded late BA settlement in resultant predictor maps suggest integrated and perhaps hierarchical settlement system(s) existed?

    iv. Do predictive maps indicate areas in which “bridge” or “link” settlements between intra-island regions exist? Particularly the postulated large late BA “primary” centers of the lowlands.

2 Study Area: The Vasilikos and Ayios Minas Midlands and Lowlands

Decades of research on the interaction between past people and the natural environment in the study area provides a foundation upon which to select the environmental variables, referred to as evidential themes in WoE predictive modelling, that are considered to influence archaeological site location selection. This section discusses settlement patterning and socioeconomics in the study area during the BA within the context of these variables.

2.1 Study Area

The study area comprises the Vasilikos, and Ayios Minas River valleys located in south-central Cyprus, an island nation in the eastern Mediterranean (Figure 1). The valleys contain the uplands of the Troodos mountains (Troodos terrane axis sequence), the midlands also called the Troodos foothills (Troodos terrane Arakapas sequence) and the lowlands containing the flatter coastal plain (circum Troodos sedimentary succession) that leads to the Mediterranean Sea forming deltas (Figures 2 and 3). These valleys are considered typical Mediterranean fluvial systems owing to their varying breadth and depth, canyon-like valleys, raised beaches, river terraces and frequent occurrence of high erosion (Schiffer 1987: 251; McNeill 1992: 284-85; Roose 1996: 13; Griesbach 2000: 16; Montanarella 2001: 202).

Figure 1: Cyprus in its eastern Mediterranean context. Google Earth, https://earth.google.com/web/

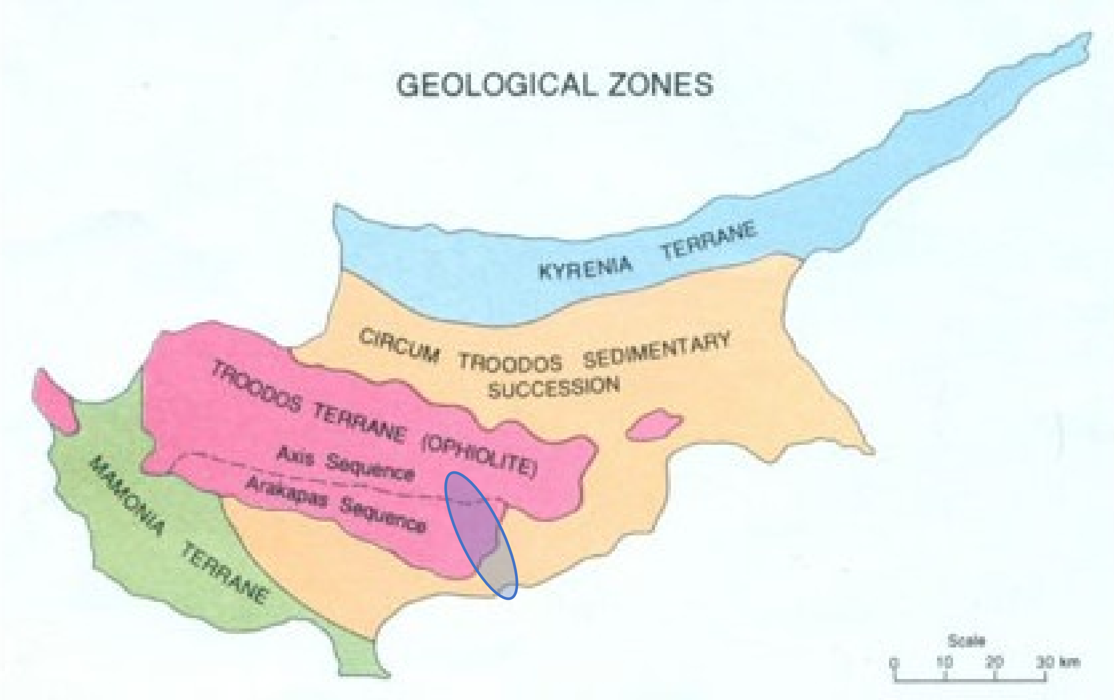


Figure 2: Major geological formations of Cyprus. Note the location of the Troodos Mountain range in pink and the orientation and general area that the two valleys of the study area occupy in blue.

2.2 Survey Boundaries

The study area comprises four main areas. This includes the full extent of the Vasilikos Valley Project (VVP) (Todd 2004; 2013) that covers the lowlands and midlands of the Vasilikos valley, the full extent of the Maroni Valley Archaeological Research Project (MVASP) (Manning and Conwell 1992) that covers the Ayios Minas valley lowlands, a small intervening area surveyed by Andreou (2014-2016) and a fourth unsurveyed area comprising most of the Ayios Minas midlands that the author will ground-truth following the results of predictive survey (Figure 3).

The VVP survey area comprises two contiguous and off-set (c. 1.8 km^2) rectangular areas stacked north to south with their longer axes oriented east to west. The northern boundary of the northern rectangle forms a 6.6 km border beginning at the Kalavassos reservoir. The eastern and western borders extend south for 5.2 km where they meet the southern rectangular area. The northern rectangle encompasses the modern towns of Kalavassos and Asgata. The southern rectangle, offset to the east by 1.8 km, runs south toward (and slightly beyond) the coast for 5.8 km and encompasses the modern towns of Mari and Zygi. The VVP employed an extensive and rural-oriented methodology that encompassed the lowlands and midlands in which long east-to-west transects were laid out in random over the c. 90 km^2 area. This method opted to leave much of the area un-surveyed in order to acquire a general picture of the archaeology over a very large area (Todd 2013: 4).

The lower portion of the Ayios Minas valley surveyed by the MVASP very nearly shares its western border with the eastern border of the VVP. The remaining sliver was surveyed (Andreou 2014-2016) to close this gap. The southern extent of the MVASP survey area proceeds stepwise east from the modern village of Zygi at 500m increments for 5.5km. The border then turns north before traveling stepwise, again at 500m increments, to the northwest and dropping south to meet the north-eastern corner of the lower rectangle of the VVP. The MVASP survey area encompasses 20km^2 and the modern villages of Maroni and Psematismenos. The MVASP employed an urban-oriented grid-based approach that intensively surveyed the entirety of the lowlands of the Ayios Minas River valley with particular emphasis on the area around the modern village of Maroni (Manning and Conwell

1992). The results of this survey have been published, but the specific locations of the sites have not and cannot be visually represented on maps in this study.

The third major component of the study area includes the unsurveyed midlands of the Ayios Minas valley (Figure 3). This area was included so that the lowlands and midlands of both valleys are included in predictive models and analysed for AoAP This area shares the north-eastern border of the VVP and northern border of the MVASP with an eastern border that aligns with the crest - highest point - of the eastern extent of the Ayios Minas River valley. The modern villages of Choirokoitia and Tochni fall within this area and it covers c. 35km^2. This area had not been subject to archaeological survey prior to predictive survey.

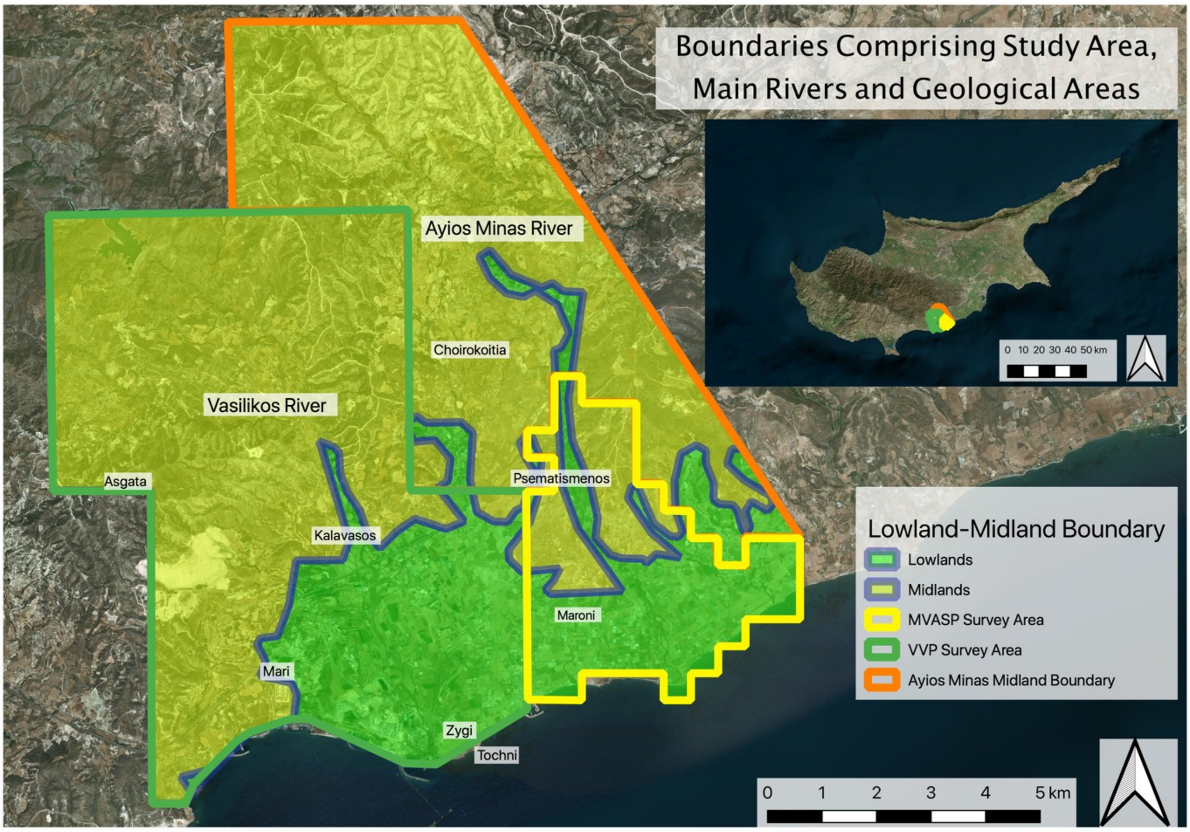


Figure 3: Study area (with inset showing position in Cyprus) indicating the components that comprise the study area including the VVP (green), MVASP (yellow) and unsurveyed Ayios Minas midlands (orange). The lowlands are infilled green and midlands infilled yellow with their boundary indicated by blue. Google Earth, https://earth.google.com/web/

2.3 Climate, Environment and Natural Resources

The climate and the natural resources of a region exert a strong influence on human behaviour (Maher et al. 2011: 2-3). In Cyprus, human arrival followed the humid Younger Dryas period as it gave way to a drier 'Cold Event' around 8200 Cal. BP (Butzer 1975: 2005; Griggs et al. 2014; Staubwasser and Weiss 2006: 378-379; Weninger et al. 2006). Palaeoclimatological evidence suggests that by 6200 Cal. BP Cyprus was experiencing prolonged summer drought and irregular winter rains very like the climate of the study area during the BA (Stanley Price 1979a: 9). The following climatological and environmental themes are considered to have exerted considerable influence on the socioeconomic strategies and settlement patterning in the study area, are central to prevailing explanatory theories and models that underpin our understanding of prehistoric Cyprus and will be used to build WoE models developed below.

2.3.1 Hydrogeology: Precipitation, Potable Water and Erosion

Precipitation
The mean annual precipitation in Cyprus can be as high as 600 mm (Toufexis 1967: 155) with the rate increasing from 400 mm nearer the coastal lowland to 800 mm in the mountainous uplands. Ninety percent of precipitation in Cyprus is confined to a 3-month period between October and December in which the soils, while saturated, also experience significant loss of moisture to run-off (Roose 1996: 22; Waters et al. 2010: 228) as well as water-table percolation and evaporation (Christodoulou 1959: 37; Boronina et al. 2003: 130). However, while only 10% of rainfall occurs between April and September, it is often torrential and can compromise crop yields and subsistence security (Christodoulou 1959: 28). The lower and middle Vasilikos and Ayios Minas River valleys fall within an elevation range of 0-200m and experience moderate rainfall of ~444mm annually, high mean air temperature (with frosts occurring 10-15 times annually) and a wind regime significantly influenced by sea breezes (Stanley Price 1979a). Inter-annual variability in rainfall indicates that 3 of every 100 years produces insufficient rainfall for dry farming resulting in famine (de Brichambaut and Wallén 1963) with historical records documenting 8 famine years, 15 serious crop failures and 5 crop failures between 1800 and 1897 (Christodoulou 1959, 28-30).

Potable Water
Prior to modernisation and the development of reservoirs, freshwater in Cyprus was acquired from rivers, streams and springs. Rivers and streams rely on autumn and winter rains and the Troodos range snow melt; and while the rivers are active during the winter, they are reduced to streams, rivulets but generally completely evaporate during the summer (Stanley Price 1979a). Modern precipitation measures indicate a largely unreliable and sometimes entirely inadequate supply for lowland dry farming, a condition exacerbated by high evaporation (Stanley Price 1979a: 11) but somewhat alleviated by three major aquifers in the Vasilikos area (Department of Water Development 1977) that would have been essential to the survival of past people (Christodoulou 1959: 40). It is noteworthy that during the Holocene, standing/lacustrine resources in the lowlands were too saline and very likely malarial to be potable (Constantinou et al. 2002: 2; Boronina et al. 2003: 135).

Erosion
The torrential nature of rainfall, arid landscape and sparse vegetation in the Vasilikos and Ayios Minas River valleys encourage high rates of erosion (McNeill 1992: 16-17; Millman and Syvitski 1992; Liquete et al. 2005: 427). During rainfall, the streams descend in torrents such that the water and sediment load exceeds the dispersal capacity of the receptor basin (McManus 2002; Liquete et al. 2005: 471) resulting in choked and perpetually shifting streams and constantly shifting flood plains (Devillers 2004). The wide, but generally shallow, streams rapidly evaporate in the hot sun leaving large down-wash debris clusters littering their beds. These natural dams impede river courses and encourage meandering or a dissipation that ceases flow altogether (Figure 4). It is argued that the high erosion and periodic torrential river flow in the valley midlands encouraged settlement near the springs and shallow aquifers that dot the Pakhna and Lefkara formations rather than the rivers and tributaries themselves (Burdon 1954: 321-22; Constantinou et al. 2002: 2, 83; Boronina et al. 2003: 135) (Figure 5 red and mid-blue areas).

As is the case today, high erosion and alluviation would have made boat navigation of these rivers largely impossible; however, some segments of the main river branches during certain times of the year could have facilitated the movement of materials and products by barge or raft (Manning and de Mita 1997). Mooring in the wider and deeper coastal inlets rather than in the deltas themselves may have been practiced as a means of avoiding the real threat of flash flooding and at least two later BA ports have been identified. While there is also evidence that sheltering sandbars existed in the Bronze Age, coastal erosion estimates of 75-100m (Gomez and Pease 1992) and more recently of up to 200m (Andreou 2016: 143) since the BA have obscured these features.

Borehole evidence in the flood plain of the Vasilikos has indicated as much as 25m of alluvial deposits (with an average of 15m) have been laid down since the BA. Periods of intense alluvial infilling have been dated (Vita-Finzi 1969; Gomez 1987), including a major phase of over-bank alluviation in the 7th millennium BP (Gomez, 1987) and at least 1.5m of sediment deposition in the 15th century A.D. linked to channel downcutting and expansion of agricultural activity (Thirgood 1987). These events have been cited as one reason for poor archaeological visibility in the lowlands and heavily truncated archaeological deposits in the midlands.

Figure 4: An example of a dry river valley segment in the middle Ayios Minas valley. Photograph taken by author in early fall.

2.3.2 Soil: Chemistry and Mechanics

While the river valleys of the study area share common geological deposits their extent and distribution, including their overlying soils vary considerably (Figure 5). This variation undoubtedly influenced settlement patterning across the study area, particularly due to a strong influence of soil chemistry and mechanics on socioeconomic behaviour. For example, the Lefkara chalk plateau and its marginal soils that comprise most of the midlands is four times larger in the Ayios Minas valley than in the Vasilikos. The means that not only do the midlands of the Vasilikos valley have a larger area of fertile soil, but it appears that the lowlands and uplands of the Ayios Minas valley were separated by what appears to be a very large infertile and largely inhospitable area. Whether this is the case is can be tested in the predictive models below.

How valley inhabitants approached subsistence farming over the BA was influenced by prevailing technology, the soils they were suited to cultivate and possibly subsistence goals. The soils that were amenable to cultivation also influenced choices on which soils to build on. The valley midlands and lowlands are covered by three soil types. The location, chemistry, and mechanics of which are central for understanding past cultivation practices and therefore settlement patterning. These include:

1. Shallow, limestone-rich, light soils in the midlands, particularly in the Pakhna/Lefkara formations which together are referred to as the Chalk Plateau. These are weakly developed mineral soils in unconsolidated materials (regosols) and weakly consolidated shallow soils (leptosols). Regosols and to an extent the less fertile leptosols are sometimes used for ‘capital intensive’ (high-input and high-financial gain) irrigated farming

but are primarily used for low volume farming (requiring terracing) and pastoral grazing (Figure 5 red and navy-blue areas).

2. Deeper alluvial/colluvial soils along midland riverbanks and into the fertile plain of the lowlands. These soils include both lime-rich fertile soils (cambisols) that are medium and fine textured materials mostly from alluvial, colluvial and aeolian deposits *and* marginal calcisols suited to low-volume grazing. In some areas, this profile also includes marginal luvisols that comprise clay that have been leached and redeposited after heavy rain. Cambisols are suited to a wide range of cultivars and are the most fertile in the midlands but require technologies, the availability of which, has varied throughout history (Figure 5, orange areas).

3. Heavy, erodible limestone-rich soils of the Apalos, Athalassa, Kakkaristra and Kalavassos formations. Poorly fertile, these soils comprise both gypsum-rich gypsisols and calcisols. Deep gypsisols close to water can be planted with a wide range of crops but require terracing to avoid severely depressed yields due to their stoniness, high propensity to erosion and inherent nutrient imbalances. While considered low in fertility, they have been consistently and at times heavily cultivated using terracing, particularly in the early and middle BA. In the absence of terraces, they are often used for low-volume grazing (Figure 5, dark pink and light pink areas).

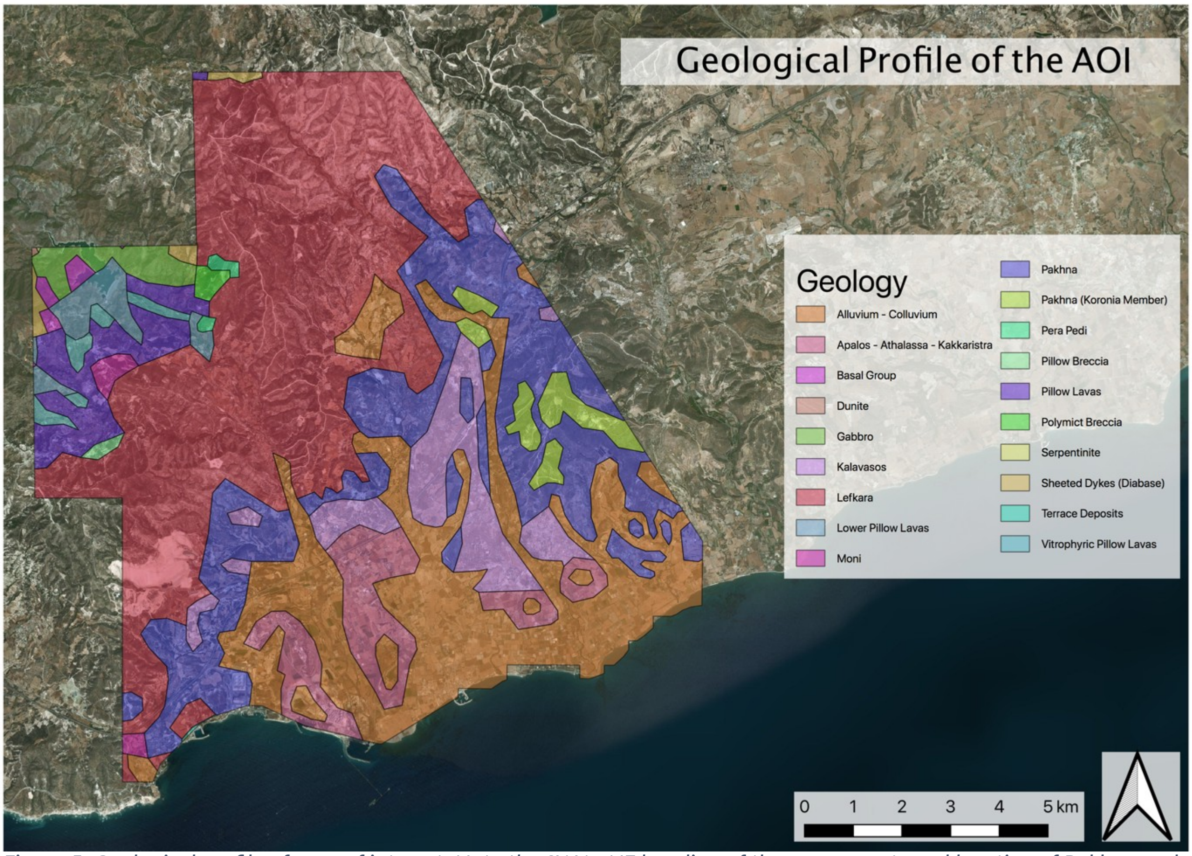


Figure 5: Geological profile of area of interest. Note the SW to NE banding of the components and location of Pakhna and Lefkara formations. The shallow, limestone-rich, light soils in the midlands, particularly in the Pakhna/Lefkara formations that in general is referred to as the Chalk Plateau comprised less fertile regosols and marginal leptosols (red and navy blue); the deeper alluvial/colluvial soils along midland riverbanks and into the fertile plain of the lowlands include lime-rich fertile cambisols but also marginal calcisols and luvisols (darker orange); and the erodible limestone heavy gypsisols and marginal calcisols of the Apalos, Athalassa, Kakkaristra and Kalavasos formations. Base map from Google Earth, https://earth.google.com/web/

Subsistence practices that could be undertaken on any given soil (cultivation, grazing) and the products grown on them (subsistence, capital-intensive) were dependent on their organic composition, mechanical characteristics, the available technology tat the time and economic incentives present at regional and inter-regional scales. These factors had a powerful influence on the pattern that settlement took at any given time. For example, the hilly terrain and shallow erosion-prone soils of the chalk plateau are considered marginal by today's standards; however, in the early and earlier middle BA these soils dominated cultivation due to technological constraints and the climatically favourable conditions of the time through terracing of finer soils (e.g., Shiel and Stewart 2007). Specifically, it was the available technology (hand plough) and modest cultivation goals (domestic-level subsistence) that made them more desirable than the heavier, clay-rich lowland varieties suited to high-input/high-yield cultivation that required draught animals and the deep plough to work with any success (Noller 2008: 28). It was only in the later middle and late BA as demand for crop surpluses and the requisite technology became available that the more labour-intensive fertile cambisols were worth cultivating. It is worth remembering that while the most fertile soils suited to grazing, dry farming, and producing the widest array of vegetation (including cultivated types) were the moister alluvial deposits skirting the river courses running from coast to uplands (Noller 2008) these areas were and remain unstable and treacherous.

2.3.3 Flora and Fauna

Decades of research has shown that the animal and plant profile of Cyprus has been continuously reconfigured due to human agency including deforestation/reforestation, the importation and hunting to extinction of fauna and the changing of wild plant profiles due to cultivation practices, pastoralism and wood burning for fuel. This research supports the selection of evidential themes that populate the models below.

Flora: Wild and Cultivated Plants

Holocene Cyprus had a rich and relatively diverse tree cover with the midland foothills and upland mountains dominated by Mediterranean evergreen trees including oak, juniper, Aleppo pine and cypress (Thiébault 2003; Jones et al. 1958: 24; Stanley Price 1979a: 13). Strabo's '*Geography*' (Heinemann, W. 1917-1935: 685) depicts a richly forested Cyprus at the turn of the millennium but noted a process of anthropogenic deforestation and transformation into a maquis and garrigue was underway (Meiggs 1982: 134-137, 397-399; Held 1989a: 107). It is estimated that deforestation from shipbuilding, copper smelting, household consumption, land clearance and crafts over a 3000-year period felled 150 km^2 of forest, an area 16 times greater than the island itself with negligible regrowth due to unfettered grazing by sheep and goats (Constantinou 1982: 22).

The current vegetation of Cyprus is so notably different than in these historical descriptions that some have argued that Strabo's term 'heavily forested' likely referred to the dense, wild maquis rather than true forest (Stanley-Price 1979a: 13-14). However, Venetian and Ottoman accounts well over 1500 hundred years later also refer to a 'forested' Cyprus (Butzer and Harris 2007) and as recently as the 18th century the Troodos was reported to have been heavily wooded by black pine, arbutus and oak, while the valleys were richly spread with maple, poplar, willow, alder and plane trees (Cobham 1908: 329-331; Butzer and Harris 2007: 1938). Some argue for several phases of deforestation over time and across space (Butzer and Harris 2007: 1938-1939; Christodoulou 1959: 227) while others claim the more arid parts of Cyprus, including the study area, appeared much as they do today (Adams and Simmons 1996a: 19-20, 22-23) (Figure 4).Given a reliance on wood for so many aspects of subsistence, the former tends to be more likely.

Today, the hot and semi-arid lowlands is home to garrigue species such as grass, rock and dwarf shrubs, xerophytic weeds, broadleaf cactus, juniper, carob, olive and date palm. Further inland, the midlands are planted with carob, fig, pistachio and almond while the uplands contain grapevines, orchards, and deciduous hardwood trees flanked by conifers and evergreens (pine and cedar, cypress, and oak). This profile is joined by seasonal patterning with a multitude of herbaceous plants covering the slopes and fallow fields between January and March, parched earth blanketed with shrubbery and snaked by relatively verdant riverbanks during the dry summer months and legume growth in the winter and spring.

Hansen (1988) has shown that the same suite of plants was exploited throughout the Mediterranean from the Neolithic into the Classical era including the 'founder crops of southwest Asia': einkorn, emmer, wheat as well as barley, peas, horse bean, lentils, vetch, and smaller amounts of olive, flax and wild fruits comprising a mixed agricultural strategy of local and imported varieties. Additionally, chickpea, grass pea, fig, grape, plum, pear and pistachio were consumed as early as the Chalcolithic period (4000 years before present) in Cyprus (Murray in Peltenburg et al. 2003: 59-71, table 4). This assemblage was supplemented in the Hellenistic period by almond, hazel and other fruits including pomegranate and citrus (Hansen 1988), foods that continue to be consumed into the modern era. Domesticates are supplemented even today by wild varieties of the midlands and uplands.

Fauna: Domestic and Wild Animals Consumed in Prehistory

The faunal profile of Cyprus has also changed over time. The earliest animals likely exploited by humans in Cyprus were the pygmy hippo and elephant of the Pleistocene (Davis 1985), but ~12,000 years ago they were either hunted to extinction or perished due to climate change (Bunimovitz and Barkai 1996; Grayson 2000; Davis 2003: 258-259; Simmons and Mandel 2007). Once gone, Cyprus was left with no mammalian herbivore larger than the mouse (Croft 2002: 172). In the Aceramic Neolithic c. 10,500 years ago fallow deer, cattle, sheep, goat, pig, fox, dog and cat were imported (Vigne et al. 2009). It is uncertain whether these were wild, domestic or some combination (Croft 2002: 174-175; Horowitz et al. 2004: 43-44). Cattle proved ill-suited to the drought prone and arid environment of Holocene Cyprus (Simmons 1998: 237-238; Sevketoglu 2000: 77; Croft 2003a: 274-275) and were replaced by pig as a major food source early on (Vigne et al. 2001: 56-57). Goat and sheep by contrast were well adapted and continue to be exploited into the modern era (Wasse 2007, fig. 10). Fallow deer remained prominent in the prehistoric Cypriot diet into the Bronze Age (Croft 2002: 174; Webb et al. 2009a: 221-224).

By the mid-3rd millennium BP cattle begin to trickle back into Cyprus (Croft 1991) along with screw-horned goat to alleviate the reduction in fallow deer (Croft 1996: 218). This importation coincides with momentous cultural, social and environmental developments, including the 'secondary products revolution' in which dairy, textile and other secondary animal products became more intensively exploited; the introduction of the cattle-drawn plough; the emergence of copper production; and the use of donkeys as draught animals (Knapp 2013: 13). The increase in stock rearing (Croft 1985: 295-296) and decrease in fallow deer is coincident with larger scale forest clearance and more open-environment farming (Knapp 2013: 14). These phenomena, coupled with a switch from goat to sheep may indicate increased stress placed on the environment, including the transformation to a maquis-rich, tree-poor landscape (Knapp 2013: 14; Croft 1989).

2.3.4 Copper, Transport Routes and Other Resources

In addition to areas of fertile soil, a diverse plant and animal profile and freshwater resources, the study area is located near one of the most productive cupriferous zones in the world (Pantazis 1966: 139). Copper ores found within the pillow lavas have figured prominently in the Cypriot economy for over 4000 years and its intensified exploitation is central to transformations to BA society figuring to this study (Knapp 2013: 3). The coastal and inland routes that were crucial for accessing and transporting copper were probably repurposed travelways that predated its exploitation (Todd 2013). Three potential routes that may have linked settlements along the coast and further inland include one along the west bank of the Vasilikos River, another skirting the lowlands of the valleys from southwest to northeast and third along the coast. Timber (Kassianidou and Knapp 2005: 235), seafood, salt (Ikram 2000: 663-668; Laubier 2005: 16-20), chert stone (Pearlman 1985, 46-47, 130, 135-136) and gypsum (Todd 2013: 6) have all been cited as relatively accessible and important resources to varying degrees throughout time in the area. These resources would all have figured in the decisions of where to settle in the past.

2.4 Modern Development

Built-up and improved areas including cultivated fields, terraces and residential, commercial, and industrial zones can adversely affect the preservation and visibility of archaeological sites. The study area is punctuated by small villages of 200-800 inhabitants, (Statistical Service of the Republic of Cyprus 2014), the historical urban cores of which have been expanded in recent years through decentralized and often unregulated construction (Manning et al. 2014). While some development can preserve archaeological sites underneath its foundations, expansion in this area requires that the bedrock be scraped level which destroys archaeological remains in the process.

The most drastic impact that modern development has had in the study area resulted from the construction of dams in the 1980s that cut off the river sediment that protected coastal sites through alluvial spreading and instead subjected them to rapid erosion by wave action (Andreou et al. 2017). Additional sources of landscape alteration include the growing tourism and development of the largest industrial centre on the island on the mouth of the Vasilikos River (including artificial ports, a cement factory, an energy station). While modern development has largely transformed the traditional economy of the study area, large parts remain designated agricultural zones and unsettled.

3 Settlement Patterning and Socioeconomics

3.1 Bronze Age Settlement Patterning in the Vasilikos and Ayios Minas Valleys

This section will provide an overview of the settlement patterning observed in the valleys and a discussion of how this patterning has been interpreted in academic archaeology using socioeconomic theory. This discussion will help contextualise the data, method and theory of the predictive models undertaken below.

3.1.1 Archaeological Exploration and Bronze Age Settlement Patterning

The VVP and MVASP surveys recorded one hundred and forty-four (n=144) archaeological sites, the majority dating to the BA (Figure 6). The term ‘site’ refers to the material remains of a wide variety of behaviour from short-term activities such as single use cooking fires and stone tool discard to the longer term habitual use of the landscape for domestic or industrial purposes. What constitutes a ‘site’ is not standardised in archaeological field survey and this remains a significant barrier to comparing and merging inter-survey results. The MVASP recorded sites as polygons proportionate to a pre-determined threshold of artefact density while the VVP recorded the centres of what they consider ‘archaeologically significant areas’ as a single GPS coordinate point. As will be discussed in section 5, the WoE method requires that all sites be converted to point data.

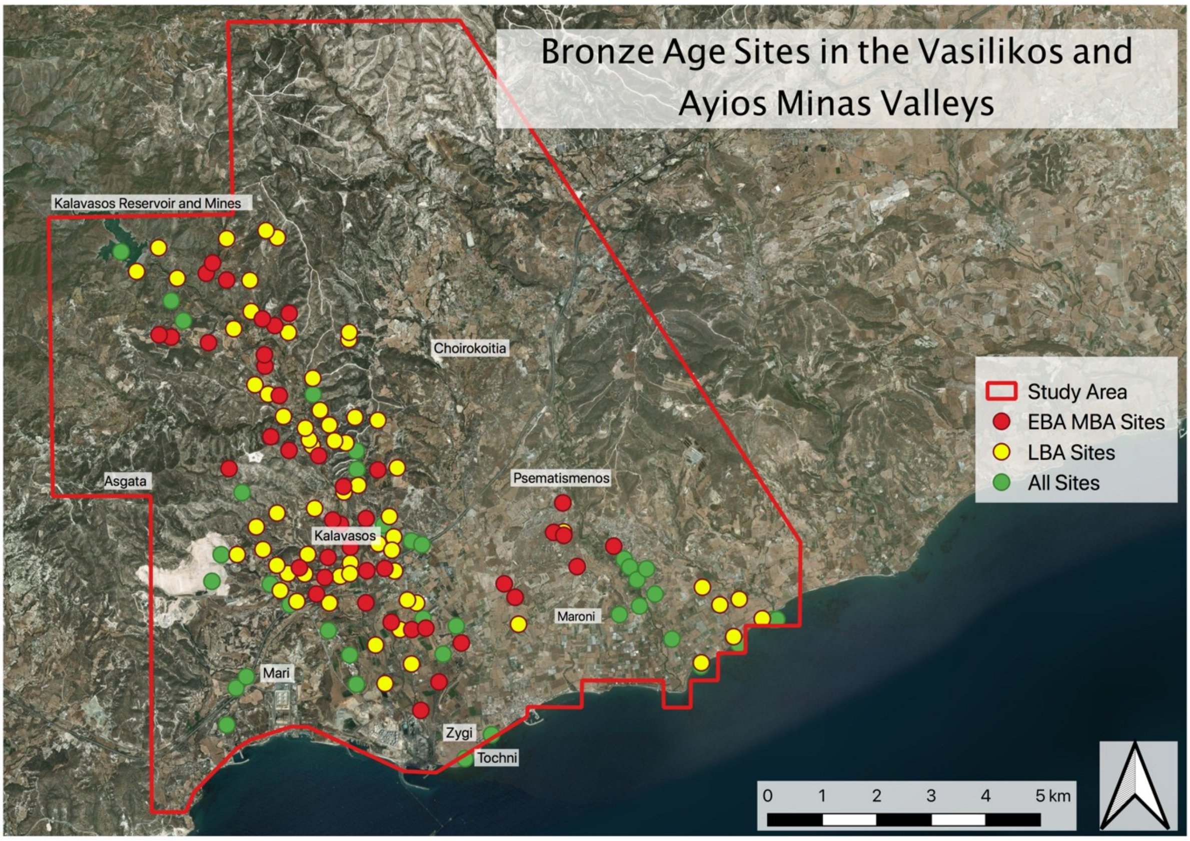


Figure 6: Sites identified by the VVP and MVASP survey projects. Early to Middle BA sites indicated in red, Late BA sites in yellow and all other chronological periods in green. Note the distinct absence of sites in the unsurveyed Ayios Minas midlands, inter-valley area, eastern Ayios Minas lowlands and western Vasilikos. Base map from Google Earth, https://earth.google.com/web/

3.1.2 History of Archaeological Investigation in the Vasilikos Valley

Archaeologically speaking, the Vasilikos valley was a terra incognita prior to the 1970’s except for sporadic descriptive reports made in the late 19th century (Reinach 1891: 188; Myres and Ohnefalsch-Richter 1899: 9) and rescue excavations by the Department of Antiquities in the early 1940’s at the village of Kalavassos (Dikaios 1953: 319). Following the Turkish invasion of the island in 1974 the VVP was established with the aim to systematically survey the lowlands and midlands of the Vasilikos valley and became one of the most intensive and productive surveys conducted in Cyprus to date (Iacovou 2007: 14). The VVP recorded 120 sites dating from the Neolithic through to the Late BA by employing an intuitive, extensive and rural-oriented approach focused on archaeologically significant areas (Todd 2004, 2013). The rediscovery of many sites led to several excavations (Rautman et al. 2003; Clark 2007) and survey projects including the Kalavassos and Maroni Built Environments (KAMBE) Project (Fisher et al. 2017) that have fuelled debate surrounding the socioeconomic and political character of the valley in the BA.

3.1.3 Observed Settlement Patterning in the Vasilikos Valley

The early BA in the Vasilikos valley is elusive and represented by a single cemetery in the north near the Kalavassos reservoir, a stark contrast to the 93 sites assigned to middle BA. Known middle BA settlement spans from the modern village of Kalavassos to the Kalavassos reservoir and mines in the north (Figure 7), is heavily concentrated around the modern village itself (to the west and north) with very little evidence nearer the coast (Todd 2013: 90), favouring the western side of the midland chalk plateaus (Andreou 2016). Todd (2013: 90) suggests this western bias may represent a well-travelled route over which long term artefact discard has occurred rather than evidence of settlements themselves. Settlement patterning has been argued to reflect the facilitation of settlement inter-visibility, upland to lowland overland routes, access to copper (Todd 2013: 92) and the deliberate settlement on infertile midland soils in a strategy to free up the fertile lowlands for cultivation, particularly in the late BA (Andreou 2016).

Excavations of late BA cemeteries and settlements in the Vasilikos valley indicate a more extensive, complex, and internationally engaged economy that somewhat contradicts the prevailing idea of island-wide disruption during this time (Manning et al. 1998; South 2000). To facilitate the international scope of the new economy and better exploit the fertile lowlands it is argued that settlement in the late BA shifted ~4km from the midlands proper to the margins of the midlands/coastal lowlands (Andreou 2016). Until recently it was thought that this late BA economic shift resulted in the abandonment of the midlands; however as will be discussed below, midland settlement endured.

One site, that lends support to this economic transformation in the late BA is Kalavassos-*Ayios Dhimitrios* (Figure 7). It stands out in late BA Vasilikos valley for its relatively ‘monumental’ architecture (particularly building X), evidence for town planning, administration (seals and script use), industrial scale storage and production of olive oil and evidence for connection to international (eastern Mediterranean) exchange networks (Fisher et al. 2017). Several other sites of the Vasilikos valley are notable for their large size and placement along the western route from the mines in the north to Kalavassos-*Ayios Dhimitrios* in the southern coastal lowlands (Todd 2013: 96). Despite their physicality and complexity many of these settlements are abandoned by around 1200 BP.

3.1.4 Archaeological Investigation in the Ayios Minas Valley

In the Ayios Minas valley in the 19th century archaeological forays were made into a BA cemetery named “Tsaroukkas” by Dümmler (1886:235), Hogarth (1889:108) and Myres (1897:171) located near the modern village of Maroni. More formal archaeological investigation was undertaken by The Cyprus Survey (see e.g., Catling 1962:148) to re-locate a “site” referred to in British Museum publications. These publications were compiled and re-published in 1980 demonstrating the importance of the area and prompting Cadogan (1996; and Cadogan et al. 2001) to excavate a major BA complex about 500m north of Tsaroukkas at Maroni-*Vournes* (Figure 7). The MVASP (1990-1995, 1997 and 2004) was undertaken to address the empirical gaps in the relationship between the two excavated areas and provide a link to and a more analytical context for the dispersed archaeological information known from the Ayios Minas Valley. To accomplish this, the MVASP employed an urban-oriented intensive survey that covered the entire study area with a grid-based system alongside a raft of techniques including pedestrian, geophysical and underwater survey and excavation of

BA and late Roman sites (Manning et al. 1994: 86-89; Manning et al. 2000; Manning et al. 2002; Manning et al. 2014).

3.1.5 Observed Settlement Patterning in the Ayios Minas Valley

In the Ayios Minas valley, evidence for early and middle BA habitation comes from excavated tombs within the modern village of Maroni (Karageorghis 1967: 299; Johnson 1980: 39-40, pl. LIX: 308-313; Georgiou 2006: 349) and two localities on its outskirts (Georgiou 2001: 49-59, 69; 2006: 350, no. 346). Additional sites were located in the 1960's by archaeological survey, but their location has not been verified (Catling 1962: 152: no.113a). The most important EBA site in the valley is found at Psematismenos village, where a settlement and cemetery have been excavated (Georgiou et al. 2011). As in the Vasilikos valley, habitation is concentrated on and light, shallow, erodible soils of the midland chalk plateau (around the modern villages of Psematismenos and Tochni, Figure 7) and near a narrow alluvial plain covered by the MVASP survey area, less than a 30-minute walk from the deeper and more fertile soils of the lowlands (Knapp 2013: 278; Manning et al. 1994: 86-89; Manning et al. 2000; Manning et al. 2002; Manning et al. 2014).

As in the Vasilikos, it is the late BA of the Ayios Minas valley has received closest attention, particularly the "Maroni Complex" (Figure 7). In similarity with Kalavassos-*Ayios Dhimitrios* in the Vasilikos valley, the Maroni complex contains a monumental building constructed above rich tombs containing evidence for large-scale processing and storage of agricultural products, particularly olive oil and is abandoned for unknown reasons by c. 1200 BP (Manning et al. 1994: 86-89; Manning et al. 2000; Manning et al. 2002; Manning et al. 2014).

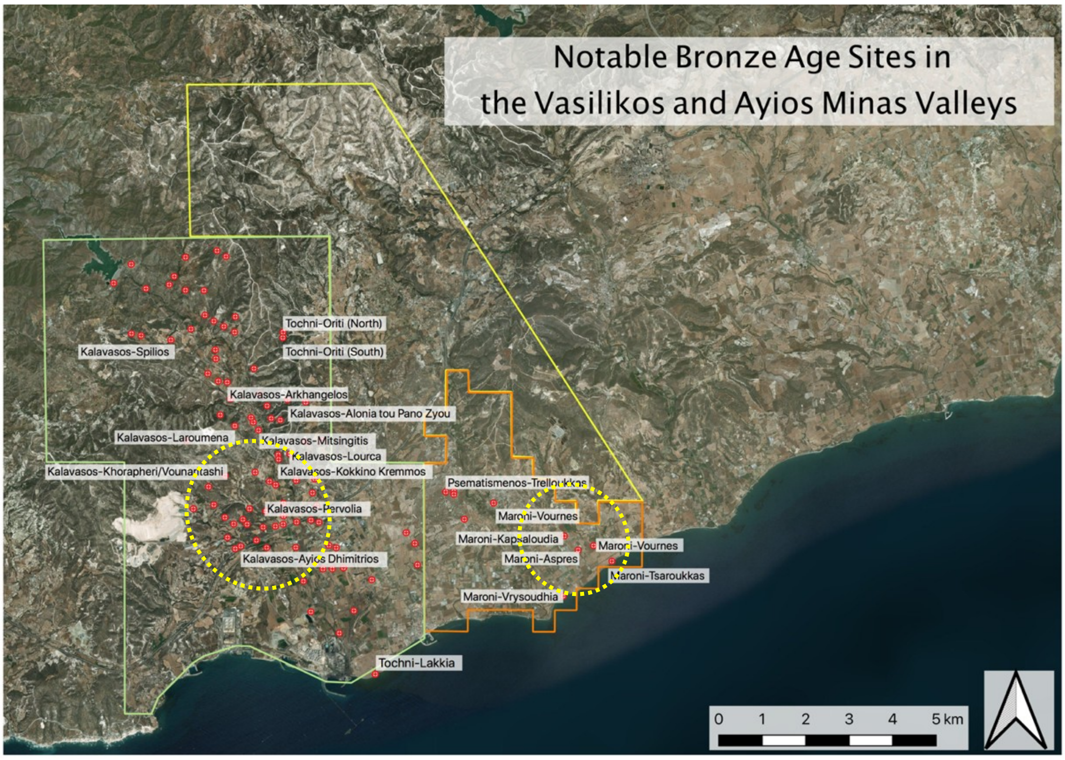


Figure 7: Prominent Late Bronze age sites in the Vasilikos and Ayios Minas valleys. Some clusters, outlined in dashed yellow, may represent mega-sites along well-travelled routes rather than separate villages but excavation is required to confirm this. If these are indeed mega-sites, then it is likely that the socioeconomic transformations that have been identified in other parts of the island were well underway in the study area as well. Base map from Google Earth, https://earth.google.com/web/

3.2 Settlement Patterning and Socioeconomics in the Vasilikos and Ayios Minas Valleys

Explanations for BA settlement patterning has been a subject of long-standing debate with natural defensibility (Catling 1962) and the proximity to luxury resources (mainly copper) and wider Mediterranean exchange networks (Keswani 1996; Georgiou 2006: 445-6) being most supported. However, little attention has been placed on more prosaic aspects including soil workability and fertility, slope, erosion, subsistence farming and ease of movement. The following outlines the current understanding of BA socioeconomics in the study area.

3.2.1 Early and Earlier Middle Bronze Age

Early BA (2400-2000 Cal BC) and earlier middle BA (2000-1750 Cal BC) inhabitants of the Vasilikos and Ayios Minas valleys lived a largely egalitarian, isolated, cooperative, village-oriented, household-based agro-pastoral existence focused on the fertile midlands and less fertile but more easily workable regosols and gypsisols. Andreou (2016) offers several mutually non-exclusive reasons as to why settlement is far more common on marginal soils prior to the late BA that helps explain the transition from early/middle BA household-based subsistence to the hierarchical settlement patterning oriented toward export markets operating by the later middle and late BA.

(a) Sufficient fertile land in midlands met population requirements: the agricultural land skirting the rivers above the fertile lowland plain supplemented by the terracing and extensive grazing of the less fertile regosols and gypsisols in the midlands was sufficient to sustain small-scale, household-based agricultural communities during the early and earlier middle BA.

(b) Technological availability: the requisite technologies for lowland cultivation, namely draught animals and deep ploughs were rare and expensive during the early BA and remained expensive into the middle BA, whereas the hand operated shallow plough and hoe were readily available, had been in use for centuries and were better suited to terracing the loose midland soils.

(c) Mixed land-use strategy: domestic level cultivation was satisfied in the marginal soils and those that had the resources and fortune could invest in capital-intensive crops in the fertile lowland soils. Due to highly mixed nature of soils in the valleys, there are always marginal pockets of soil adjacent to fertile ones and given the choice inhabitants almost exclusively settled on marginal soils regardless of what they cultivated. This is presumably because it made little sense to physically build on the fertile lowlands, except in a capacity required by the capital-intensive crops grown there (i.e., storage, processing buildings). This selection bias of settling on marginal soils presumably intensified as high-input/high-yield cultivation increased.

3.2.2 Later Middle BA and Late Bronze Age

For various reasons, by the end of the middle BA people were moving away from egalitarian, isolated, cooperative, village-oriented, household-based agro-pastoral economy to a socially stratified, international, competitive, and town-centred society (Keswani 1996; Webb 2005; Knapp 2013: 348-349). It remains unclear as to what degree this was the case in the study area, particularly in the unsurveyed Ayios Minas midlands and how subsistence practices figured in this process. Regardless, by the end of the middle BA most of the island had been settled and population centres in many areas far exceeded the size of preceding period (Knapp 2013: 350). In this regard, the study area also grew both in increased settlement numbers and population density, particularly in the Vasilikos valley with Kalavassos-*Ayios Dhimitrios* and the cluster of sites around it (Todd 2004) but also in the Ayios Minas valley with Maroni-*Tsaroukkas/Vournes* “complex” (Manning and DeMita 1997; Manning et al. 2002) (Figure 7). It is noteworthy that many of these clusters may have been ‘mega-sites’

(Knapp 2013: 351) rather than amalgamations of distinct villages, though this designation awaits confirmation by excavation.

Some of these sites contain evidence for production of capital-intensive (high-input and high-financial gain) goods including olives and copper for exchange within the region or to be fed into international export markets (Keswani 1993). Some have argued, that like other regions of the eastern Mediterranean and Near East, the successful exploitation of these resources and ability to produce food surpluses enabled the emergence of a politico-economic elite and centralisation of socio-political authority (Knapp 2013: 351-52). Two candidates for this are the lowland sites of Kalavassos-*Ayios Dhimitrios* in the Vasilikos valley (South and Todd 1985; South 1989; 1996) and the "Maroni Complex" of the Ayios Minas valley (Manning et al. 1994: 86-89; Manning et al. 2000; Manning et al. 2002; Manning et al. 2014).

3.3 Current Theories Explaining Settlement Patterning

3.3.1 Regional Models

Models have been developed to account for the settlement patterning of the later middle and late BA. As early as the 1960's, Catling (1962) proposed a tripartite system comprising upland copper mines, midland/lowland agricultural villages and prosperous coastal lowland towns engaged in metal working and trade. Keswani (1996; 2004:154-156) provided a more nuanced version by suggesting that a 'complex web of tributary and exchange relations linking coastal centres, inland centres, mining, and agricultural villages' existed (Keswani 1993: 78).

Keswani (1993) proposed that regions (synonymous with valleys) organised according to one of two settlement patterning models. These models are distinguished by the distance between what she terms 'primary' coastal centres engaged in export of copper items (and perhaps other goods) and the sources of raw copper they processed (Keswani 1993: 79). If the distance was relatively small, primary centres could directly undertake extraction and beneficiation, but having exhausted their labour force in doing so, were reliant on acquiring food and other necessities from satellite agricultural settlements (Figure 8). In exchange, they would supply these support villages with "staple" wealth in the form of expensive processed foodstuffs such as olive oil that they would acquire as olives from these settlements. The equipment for industrial-level olive oil production was expensive and would allow the "primary" centre to both fund copper mining and export the oil they produced above what they would send to "secondary" sites. However, if the distance was great, then primary centres had to rely on 'secondary' and perhaps even 'intermediary' settlements for the acquisition, processing, and transport of copper that the "primary" sites would fund using portable and high value "wealth" finance such as finished copper items that would confer status on these support villages (Figure 9).

Keswani (1993: 79) suggests that the site of Kalavassos-*Ayios-Dhimitrios* was probably organised in accordance with the second model, that is primary centres settled sufficiently close to a copper resource that they were directly engaged with its extraction, processing, transportation, and production into finished goods. Their primary economic interaction with 'secondary' settlements was not tied to copper exploitation but the exchange of 'staple wealth', in their cases olive oil for subsistence goods. These settlements systems, regardless of the type of wealth they were exchanging were believed to be hierarchical with a clear power imbalance favouring primary centres (Keswani 1993; Knapp 2013).

Evidence suggest that the primary centres of both valleys probably relied to a degree on other settlements for their raw copper but also at least some of their subsistence requirements. This likelihood establishes Keswani's (1993) models are a helpful abstraction of the spectrum of relationships possible in these valleys, particularly given the proximity of what appear to be two primary centres.

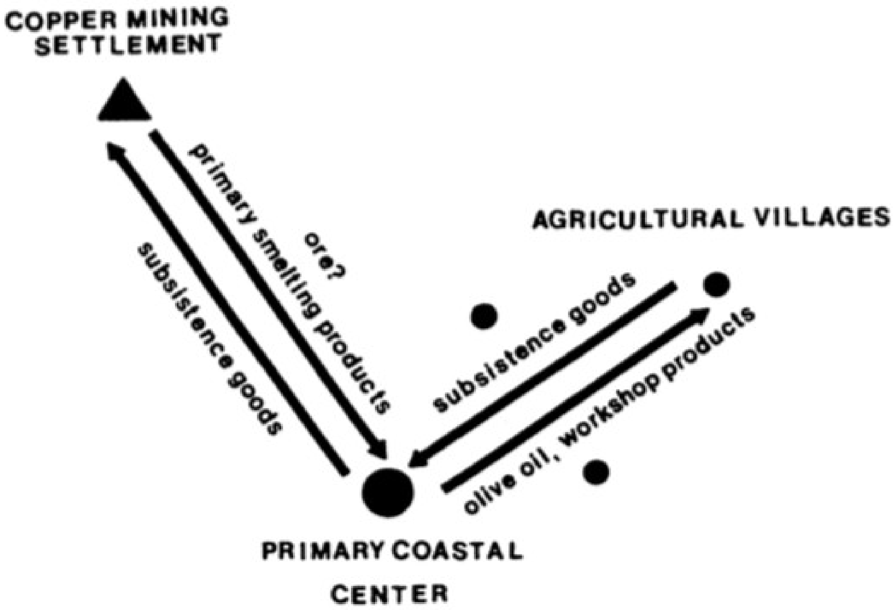


Figure 8: Settlement and exchange system in which the primary centre is close to the copper source and relies on other settlements not for copper exploitation, but subsistence as staple

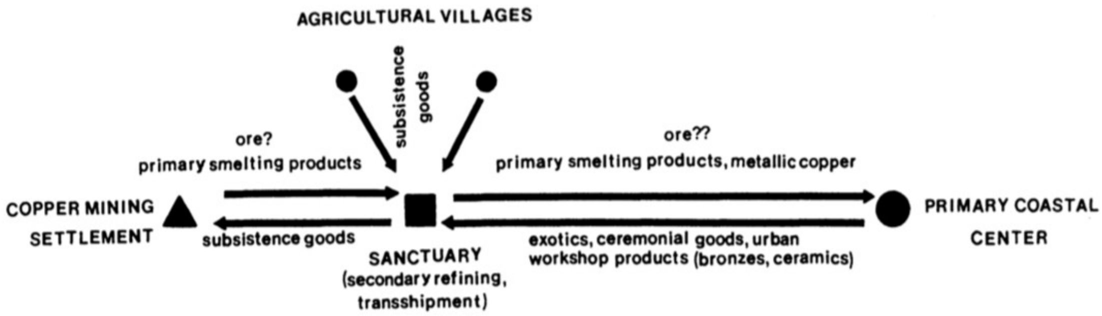


Figure 9: Settlement patterning and exchange system operating in a region where the primary center is distant from the copper source and requires intermediaries to facilitate acquisition, initial processing and transport. In this case, wealth finance is exchanged for this assistance.

3.3.2 General Model

Building on the regional settlement models by Catling (1962) and Keswani (1993), Knapp (2013: 354) developed a general 'social model' applicable to the entire island in the LBA by outlining some of the environmental, agricultural, metallurgical, and politico-economic processes operating over the landscape. These processes are outlined alongside a proposed site hierarchy that may have been in operation to facilitate them (Figure 10). The tiers are correlated with certain activities/roles and resources which are in turn linked closely to geological zones. Primary tier sites were situated on the coastal lowlands, secondary tier sites on the midlands and tertiary/periphery tier sites on the midlands/uplands. Tiers are also closely associated with size of settlement (Keswani 1993; Knapp 1997: 53-63). The functions of the tiers of Knapp's (2013) model can be summarised as:

- Primary Tier: Coastal centres (commercial, ceremonial, administrative, production).
- Secondary Tier: Inland towns (administrative, production, transport, some storage).

- Tertiary Tier: Smaller inland sites (ceremonial, production, transport, some storage).
- Periphery Tier: Agricultural and ceramic producing villages, mining sites (production, storage, transport).

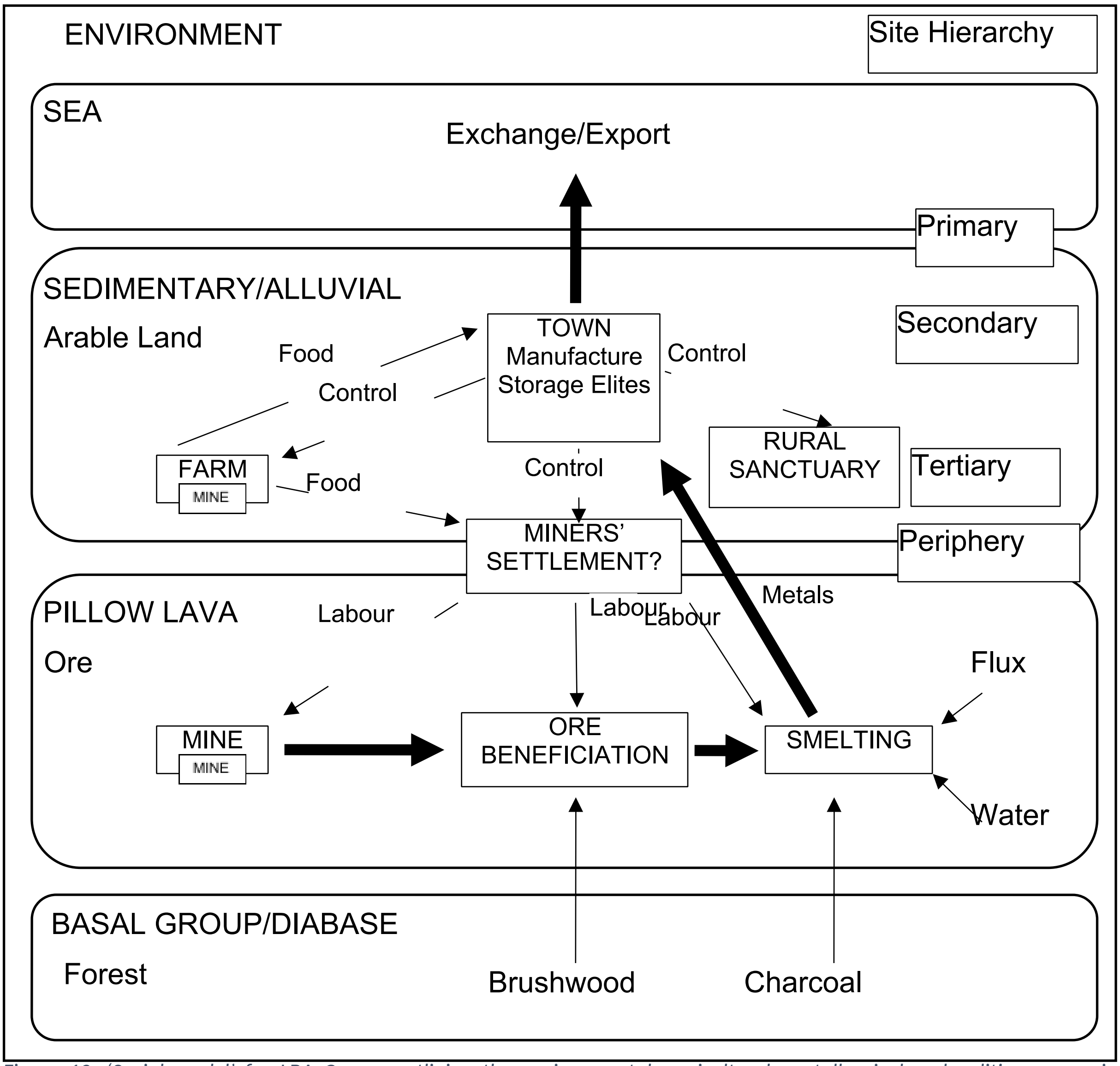


Figure 10: 'Social model' for LBA Cyprus outlining the environmental, agricultural, metallurgical and politico-economic processes influencing settlement patterning. These processes are outlined alongside a proposed site hierarchy and pre-suppose a power imbalance favoring primary centres (Knapp 2013: 354).

At this stage it is reasonable to reserve categorising sites and AoAP as belonging to a particular tier until the results of predictive modelling can provide guidance. Before conducting the predictive model and analysing the data, a review of the history of spatial analysis in archaeology including predictive modelling will be provided to help justify the choice of the WoE method for this study.

4 Spatial Analysis in Archaeology and Weights of Evidence Predictive Modelling

4.1 A Brief History of Survey, GIS and Predictive Modelling in Archaeology

Modern archaeological survey developed from within the 'Processual' archaeology school of thought of the 1960's as an attempt to increase the scientific rigor of the discipline and address the challenges of archaeological heritage management (King 1984). Survey encouraged settlement pattern studies (Wiley 1953; 1956; see Kohler 1988) which claimed that archaeologists could identify the ecological factors that determined where people chose to settle and from this reconstruct the logic system behind these choices (adapted by Chisholm 1962 and Higgs and Vita-Finzi 1972 from geographical location theory set out by Isard 1956). The processual approach claimed that settlement patterning and the early subsistence economy were two of many phenomena that archaeologists believed could be explained by universal rules or laws. This period saw the proliferation of quantitative approaches in ground survey including sampling and spatial analysis (Mueller 1975; Hodder and Orton 1976; Clarke 1977) developed most notably by Kvamme (1983; 1984; 1988) but also Kohler and Parker (1986), Judge and Sebastian (1988) and Warren (1990).

In part, in reaction to the rigid determinism of "Processual" techniques, 'post-Processual' methods emerged in the 1980's and sought to increase the spatial resolution of surveys (e.g., Keller and Rupp 1983, Cherry et al. 1991, Jameson et al. 1994), improve the quality and depth of data used to help reconstruct settlement patterning and broaden the idea of site to "off-site" and "non-site" by including all material, irrespective of an association with permanent structures or particular behaviours. Processualists countered that "post-processual" theory-driven methods relied too heavily on speculation (Whitley 2004; 2005) resulting in unverifiable claims that lacked a known (comparable) dataset (Verhagen 2007: 15) and a sophisticated understanding of natural and human post-depositional phenomena including erosion, soil formation, alluviation/colluviation, coastal modification and archaeobotany. Despite these legitimate claims, post-processual critique has encouraged more self-aware approach that tempered the most deterministic of claims, enforced more rigorous recording systems and introduced the concept of the relational database (Alcock and Cherry 2004b: 3). Some conservative aspects of archaeological survey influenced by the scientific positivism that remain indispensable today include the concern for site type, the role of the environment (Bintliff et al. 1999: 139) and sampling and uncertainty (Bintliff 2000; Given 2013: 3).

4.1.1 Geographical Information Science

Two powerful tools, geographical positioning systems (GPS) and geographical information systems (GIS) were adopted by archaeologists in the late 1980's and early 1990's and were instrumental in promoting environmental determinism in settlement pattering and socioeconomic behaviour studies (Gaffney and van Leusen 1995; Wheatley 1996; Wansleeben and Verhart 1997). The application of these tools was roundly criticized for dehumanising the past (Flannery 1976; Tilley 1994; Trigger 2006: 444-78; Stark and Garraty 2010: 41) and notable targets included the eco-environmental approaches that mathematically spatialized sites, natural resources, paths and time (Wilkinson 2003: 211; Renfrew and Bahn 2006: 183) and imposed rigid hierarchy on settlement in the landscape such as in central place theory (Hodges 1987: 119-20; Renfrew and Bahn 2006: 182-83), Thiessen polygon analysis (Renfrew and Bahn 2006: 183) and XTENT Modelling (Renfrew and Bahn 2006: 183-84, 186). With the strong push to "people the past", "post-Processual" interpretations attempted to highlight the simplicity of traditional 'settlement pattern studies' (Athanassopoulos and Wandsnider 2004: 8) by incorporating social theory and the individual as "agent" (e.g., Hodder 1982; Renfrew 1984; Shanks and Tilley 1987).

To an extent, the general criticisms were reasonable and have demonstrated that the relationship between people and the natural environment is clearly reflexive rather than deterministic. However, the power and sophistication of GIS and GPS has enabled huge datasets to be analysed in complex ways that arguably lie beyond the influence of small groups and individuals. The results of studies using these tools are visualised in powerfully communicative maps and disseminated digitally to most anywhere on earth. GIS can model space and time and their attributes, can spatialize material culture and by extension past human behaviour. Some researchers have controversially argued that the employment of GIS in archaeology has increased its potential to do 'hard science', while others maintain that that GIS can mask the extreme complexity of spatial analysis behind a friendly general user interface (summary in Howey et al. 2017). These criticisms are fair; however, they reflect user choice, knowledge and conduct rather than the process of using the tools themselves and it is undeniable that analysis which would have taken months and perhaps years before GIS, can now be accomplished by a competent analyst quickly and efficiently in rigorously produced and comprehensible maps at scales ranging from the very small (excavation) to the very large (regional analysis). How these maps are interpreted is where caution and restraint and humility must be exercised.

The role of GIS in academic and commercial archaeology has increased dramatically since its implementation in the 1980's (Verhagen 2007) and various volumes now exist on the topic detailing methods and workflows that aim for conscientious and competent application (Allen et al. 1990; Lock and Stančič 1995; Wheatley and Gillings 2002; Chapman 2006; Conolly and Lake 2006). One powerful tool that GIS has enabled archaeologists to take up is predictive modelling.

4.1.2 Predictive Modelling

The theory underpinning predictive modelling assumes that the distribution of archaeological sites is not random and that archaeologists can reconstruct some of the logic system employed by ancient people in their choice of settlement (Verhagen 2007: 9, 13). At a minimum, predictive modelling tries to predict 'the location of archaeological sites or materials in a region, based either on a sample of sites from that region or on fundamental notions concerning human behaviour' (Kohler and Parker, 1986:400). However, some models may attempt to date, classify, or identify additional characteristics of the archaeological record, but if such properties are not available, a non-specific predictive model can be produced (Verhagen 2007: 101).

Predictive models can be approached from a data-driven (inductive) or theory-driven (deductive) methodological framework. Data-driven models begin with site location data and make estimates or inferences regarding the overall spatial distribution of archaeological material in that sampling universe (Kohler 1988; Neuman 1997). The main goal is to derive meaningful correlations between site location and environmental attributes and use these relationships to determine the location of unknown sites. Environmental attributes, referred to as 'evidential themes' in this study, can be any spatialized phenomenon. However, archaeological models often use geology, modern land use, elevation, slope and proximity to water bodies such as rivers as evidential themes. Any notable correlations are then applied to a larger area, to determine the most likely location of new archaeological sites.

Initially, statistical, and spatial analysis techniques for data-driven predictive modelling were more common and respected, in which the work of Kvamme (1983, 1984, 1988) is seminal. GIS-based data-driven modelling was already used in the United States as early as the mid-1980s, and the foundations of the 'American way' of predictive modelling are laid out in several publications, the most influential of which were published by Kohler and Parker (1986) and Judge and Sebastian (1988). By then, the methodology was sufficiently established to permit Warren (1990) to provide a 'recipe' on how to apply logistic regression to obtain statistical correlations and predictions.

Theory-driven method begins with the formulation of a hypothesis that posits which evidential themes were of most influenced past peoples' selection of settlement location and proceeds by weighing their "influence" on site location selection either intuitively or using statistical tools. Theory-driven methods often include less commonly used social and cultural evidential themes (Stančič et al. 1999; Verhagen 2007 and Garcia et al. 2013) including view-shed analysis, proximity to, Euclidean distance and cost distance. The theory-driven method saw its first published example following the development of a computer simulation by Chadwick (1978). Later, Doorn (1993) arrived at a general explanation of settlement location in northwest Greece by rating four variables (communication, safety, availability of water and quality of agricultural land) differently for each model. The attraction of these models, which were later explored more thoroughly by Whitley (2004, 2005) resides in their ease of use and ability to contrast them with known settlement patterns to generate hypotheses concerning actual location preferences.

These advantages are also the dangers, as models can be highly speculative and give rise to explanations of site location from a limited environmental or economic perspective. Moreover, they require an archaeological data set to be tested and do not yield their bias in any obvious or intuitive way. Other criticisms include the prevalence of 'low performing' models due to the use or concealment of incomplete archaeological data sets, their bias selection of evidential themes, the neglect of cultural factors and an ignorance of the changing landscape (Ciminale et al. 2009; Gallo et al. 2009; van Leusen et al. 2005; Wansleeben and Verhart 1997; Wheatley and Gillings, 2002; Kammermans and Wansleeben 1999; Sebastian and Judge 1988).

Verhagen (2007) has outlined the 'big issues' that face archaeologists in developing models of more accurate and higher predictive power including representing uncertainty, overcoming poor sampling/adjusting for variable correlations and establishing model thresholds based on model purpose. He has also observed that 'hard science' techniques have been regarded with suspicion by archaeologists, particularly statistical methods, and the mathematical inner workings of GIS because they are poorly understood (Verhagen 2007: 16). Many predictive maps have been created by archaeologists that were not, or cannot, be subject to an assessment of their quality (Verhagen et al. 2010: 1).

Both the inductive and deductive schools are now recognised as making useful contributions to method and theory. The clash of these schools of thought has encouraged many proponents of predictive modelling to be more introspective of their own methods and practices and pursue a more humanistic approach while maintaining the importance of the environment, settlement patterning and statistical rigor of their analysis. Walker (2012), has expressed this melding as a softening of the deterministic ecology approach for one in which landscape phenomena are the backdrop that affects, limits or determines cultural forms. Each aspect of the natural and cultural environment is an indicator of cultural transformation in the investigated region (Niknami 2007) that can be considered as including or excluding factors for the presence of archaeological sites and their environmental and social characteristics. Known sites are treated as case studies that contain associations that help us understand the factors which influenced their position in space, and consequently, to find settlement rules inside the models adopted to make predictions (Stančič et al. 2001).

This study is also a synthetic approach (Wheatley and Gillings 2002; Verhagen et al. 2000; 2007: 71) as much of the guiding research used to select evidential themes was arrived at by deduction while the model is data-driven by deriving the training theme from the large number of sites recorded during prior surveys in the study area. Wider agreement that conservative models (e.g., Hodges 1987 reconstruction of economic interaction within the natural environment) serve as a useful first step toward more detailed understanding of the past (Given and Knapp 2003: 8; Verhagen 2007: 17) is occurring. Many modellers approach the undertaking from the perspective that if the model works at the practical level and correctly assigns archaeological sites to zones of high probability, then explanation could perhaps be of secondary importance (Verhagen 2007: 17). With an appropriate selection of method, predictive models can be expanded with cultural data when and if it becomes available (e.g., See Ridges 2006).

Given (2013) argues that the data can in fact enable the appraisal of sites and material clusters as socio-political entities influenced by and influencing the surrounding natural and cultural environment while coping with population and resource stresses and managing human relations. This study meets this debate in the middle suggesting that these general models can be supplemented by interpretations as evidence becomes available with what is considered a more humanistic and deeper consideration for the socio-political dimension, particularly with consideration for concepts of resource exploitation and control, the emergence of elite groups and centres (e.g., Gamble 1982; Renfrew and Wagstaff 1982) and the development of social 'complexity'.

4.2 Weights of Evidence Predictive Modelling

In archaeology, many predictive models employ relatively simple methods such as map algebra (Podobnikar et al. 2001; Brandt et al. 1992 and Stančič et al. 1999) that lack the ability to address the 'big issues' of failing to represent uncertainty, overcoming poor sampling/adjusting for variable correlations and establishing model thresholds based on model purpose (Verhagen 2007; Alexakis et al. 2011). Fortunately, methods of predictive modelling exist that do address these problems. Dempster-Shafer modelling and Bayesian statistics (central to the Weights-of-Evidence method used in this study) are two useful approaches for addressing uncertainty, ignorance, and bias.

The WoE method combines spatial data from diverse sources to describe and analyse interactions, provide support for decision makers, and make predictive models (Raines et al. 2000: 45). As a data-driven method, WoE employs Bayesian statistics to calculate the strength of the spatial association between a training theme (archaeological sites) and the classes of evidential themes (spatialised environmental, anthropogenic and/or landscape phenomena) by first assigning weights to these evidential themes that represent the strength of their spatial relationship to the training theme and then employing a mathematical technique to sum them into a prospectivity map, referred to as a response raster. Each cell in the response raster is represented by the probability that it will contain a training point. Evidential themes can be diverse and represented by categorical values and/or ordered values. The WoE method was selected for the following reasons:

4.2.1 User-Friendly Operation and Display of Results

In the context of ArcGIS, the WoE method can be implemented through "ArcSDM", a toolkit developed by geologists and computer programmers, chiefly from the Geological Survey of Canada and the U.S. Geological Survey. The toolkit guides the modeller through a comprehensible workflow that clearly outlines the data requirements and parameters of the WoE method (Sawatzky et al. 2004; Sawatsky et al. 2009) and produces relatively straightforward results as tables and maps that are more easily interpreted by the non-specialists (Raines 2000) and amenable to presentation and publication.

4.2.2 Handles Uncertainty and Bias

Many sources of bias can influence the process of developing and results of predictive models and in the procedures used to collect and organise the archaeological datasets they use. These phenomena detract from the power and validity of models if overlooked or ignored. The results of the WoE method are open to validation including the evaluation of model precision and accuracy, in the case of this study by applying the Kvamme gain statistic (Kohler 1988; Kohler and Parker 1986; Kvamme 1988; Moon 1993; Orton 2000; Shennan 1997).

Bias is not only present in the model methodology, but also the way in which data was sampled. Sampling issues including the selection of poorly distributed sites, correlation sample location bias, non-systematic sampling and imbalanced sampling are all serious issues that are not so clearly remedied because they indicate fundamental oversights and ignorance at the data collection stage (Verhagen 20017). As has been addressed above, the VVP and MVASP surveys employed quite distinct data collection strategies, however both survey projects skewed their datasets toward the Bronze Age. How this bias is addressed in this study will be discussed in section 5: Data and Methods.

4.2.3 Methodological Flexibility

ArcSDM offers several alternative data-driven methods to WoE including logistic regression (LR), neural network (NN) methods, a knowledge-driven method, and fuzzy logic (Sawatzky et al. 2009a). This may prove useful in future research as it enables the modeller to compare method against one another and ideally ground truth campaigns. The modeller can also determine which method best identifies and handles uncertainty and other forms of bias and whether datasets and contexts are better served by different approaches.

5. Data and Methods: Weights of Evidence Predictive Modelling

The weights of evidence (WoE) method below employs seven evidential themes (geology, hydrogeology, river course, vegetation, land use, soil and slope) to calculate a multi-map signature that visualises archaeological site potential in the Vasilikos and Ayios Minas valley lowlands and midlands. In WoE modelling, the log of the posterior odds of an archaeological site occurrence being located within a unit of area is determined by adding a weight for each evidential theme map to the log of the prior odds; the final product is a map of posterior probability, or archaeological potential. These results are then interpreted using theories of settlement patterning socioeconomics and settlement patterning in the BA as well as ground-truth survey results. The WoE workflow can be generalised into four essential steps and three optional steps, the latter group involving an additional measure of model validation and a means of ranking and prioritising areas of interest for ground survey (Figure 11).

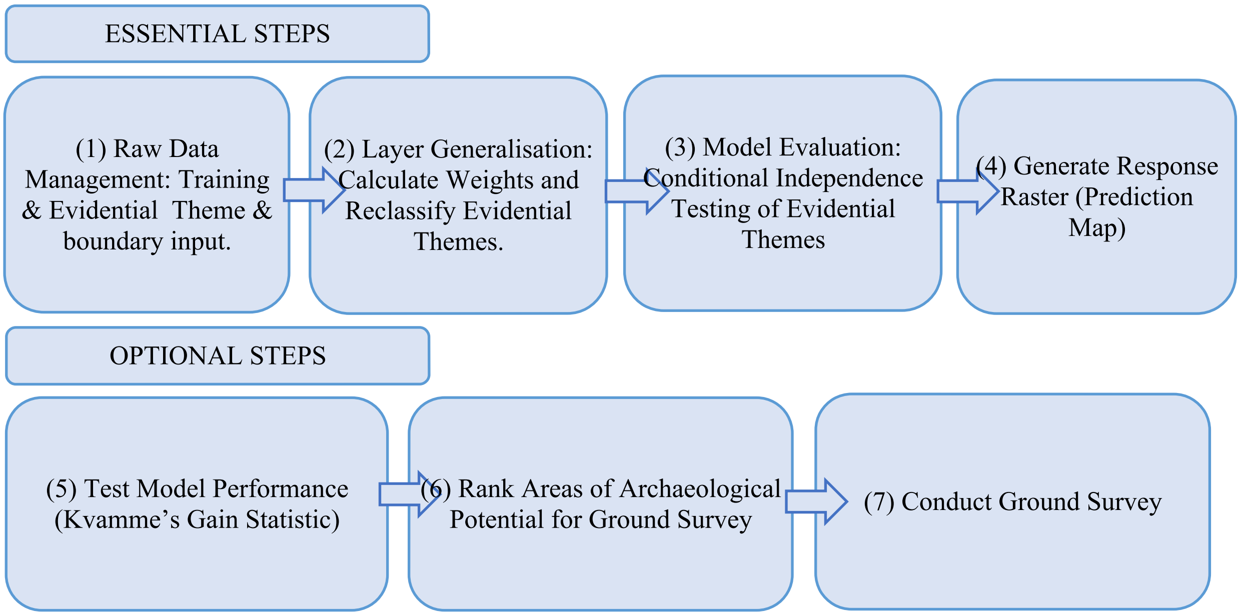


Figure 11: WoE workflow. Essential and recommended steps for further model data validation and ground survey campaign preparation. Figure created by author.

5.1 Essential Steps: Weights of Evidence Predictive Modelling

5.1.1 Step 1: Select Boundary, Training and Evidential Themes and Cell size

This step involves the selection and processing of:

1) Boundary: a single polygon that contains all sites of the training theme and encompasses the area you are predicting occurrences for.

2) Training theme: a sub-set of the phenomena of interest, in this case archaeological sites.

3) Evidential theme(s): a set of spatialised layers representing environmental and/or anthropogenic variables that are believed to influence location of the phenomena of interest.

4) Prior to data processing, an important consideration is the selection of a cell size for the model data, particularly as many evidential themes must be converted from vector (points lines and polygons) to raster (pixel cells) format. The cell size used for this model is 100m^2 as it reflects the size of the average archaeological site, the scale/resolution of the input data, the desired output of the final prediction map, a scale that can be relocated using consumer grade GPS (resolution of c. 10m) and

minimises loss in spatial resolution when converting from the original vector format to raster.

Boundary Details
The boundary for this study comprises the VVP and MVASP survey areas which cover the Vasilikos lowlands and midlands and the Ayios Minas lowlands respectively and a third unsurveyed area comprising the Ayios Minas midlands. These areas ensure that any comparative analysis between the valleys uses data from the lowland and midland geological zones of the two valleys. The VVP boundary was scanned from a print source (Todd 2013), georeferenced and digitized in ArcGIS as a polygon shapefile by the author. The MVASP project boundary was acquired from G.Andreou, the co-director of the project as a polygon shapefile. The Ayios Minas midlands boundary was digitized by the author as a polygon shapefile, ensuring that its western and southern boundaries abutted the VVP and MVASP survey boundaries respectively while the eastern and northern boundaries adhere to the crest of the Ayios Minas valley edge and the geological changes signifying the transition from valley midlands to uplands, namely the Pakhna volcanic formation (see Figure 5). Please see table C: Boundary Data Set in appendix A for further details.

Training theme Details
Predictive models are used to inform two aims of this study. The first is to model where archaeological sites, regardless of chronological period, might be found to inform future field work and mitigate the destructive effects of development. This aim requires the extraction of a training theme that does not discriminate based on chronological affiliation (i.e., sites from the Neolithic, BA, Roman era, Medieval, etc). The second aim seeks to explain the important shift in both settlement patterning and socioeconomic organisation between the early/middle and late BA. To predict where yet unknown sites might exist within these two halves of the BA and compare them to one another requires two models and therefore two training themes, one comprising early to middle BA sites, and another extracted from late BA sites.

Each training theme was drawn from the 144 total sites identified by the VVP (n=120) and MVASP (n=24) surveys (Figure 12). VVP sites were scanned from a paper source (Todd 2013), georeferenced and digitized in ArcGIS as a point shapefile by the author. MVASP site data was acquired from G.Andreou, the co-director of the project as a polygon shapefile and converted to points using the "Feature to Point" tool in the Features toolkit of ArcGIS by the author as is required by the WoE method. This conversion was executed to calculate the feature angle based on the longest segment on the polygon feature to retain accuracy. Attribute data for the VVP site layer had to be manually populated by the author, including site names and their chronological designation. Geographical coordinates were auto generated as a by-product of the georeferencing process. This attribute data was already present in the MVASP site shapefile, however as many are not published, some metadata has been redacted in this study.

The WoE method requires that there is only one training point per unit cell and that training themes extracted from datasets exceeding 50 sites must be randomly selected (Bonham-Carter 1994). The early to middle BA and late BA training themes satisfy these criteria. However, the training theme for all archaeological sites required manual reduction using the 'Subset Features' tool in the 'Geostatistical toolkit' because the in-built 'Training Sites Reduction' tool in the WoE toolkit repeatedly failed to execute. Further details of processing are outlined in table A, appendix A. Chronological and typological designations (where available) for the 144 sites identified by the VVP and MVASP are outlined in tables D and E respectively in appendix A.

Evidential Theme Details

Evidential themes constitute spatial phenomena representing aspects of the natural and anthropogenic environment that can incorporated into predictive models by random selection or chosen based on research indicating their influence on site location selection in the past or archaeological visibility in the present. In this study, evidential themes were selected for their perceived influence upon settlement patterning and socioeconomic strategies pursued during the BA. By applying these evidential themes across the two valleys it is anticipated that we can compare their respective patterns of settlement and infer the socioeconomic strategies developed and test these patterns against prevailing theory.

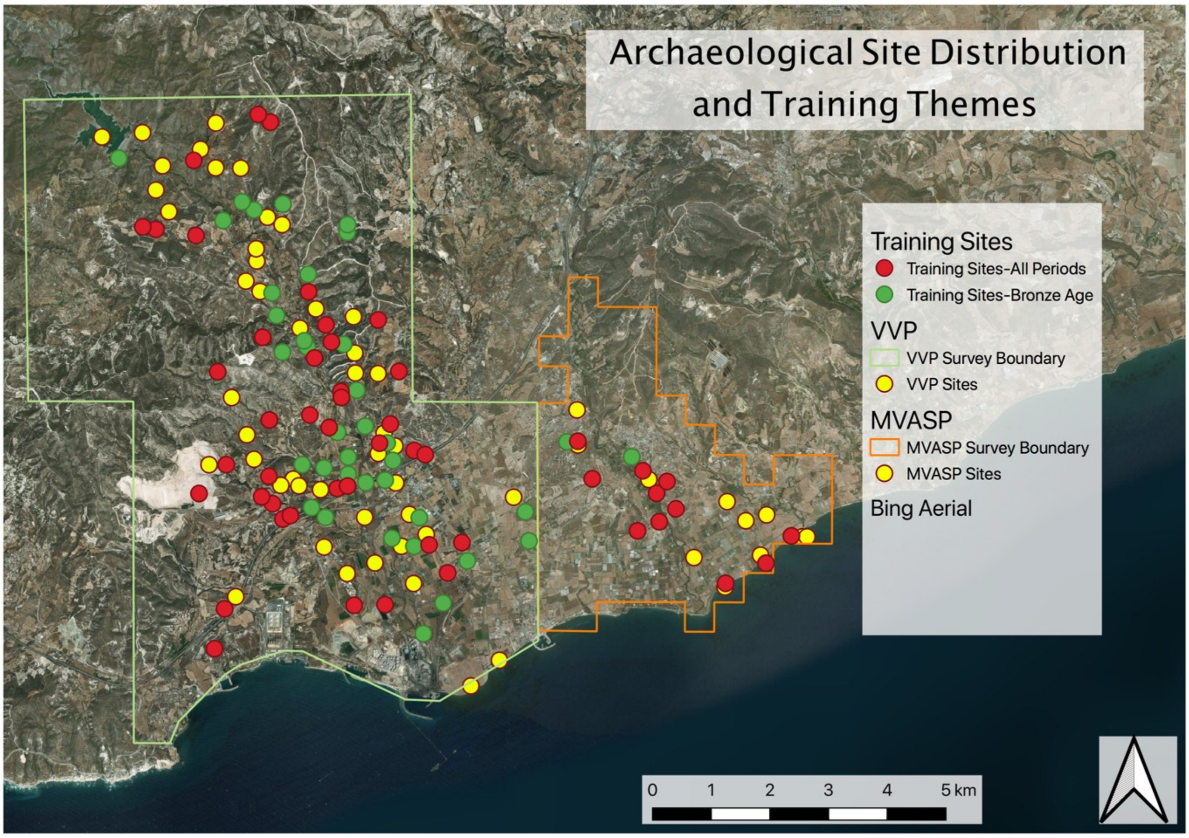


Figure 12: Map of the study area indicating the site comprising the training themes for All Chronological periods (in red) and the Bronze Age only (in green). All remaining sites that were not included in the selection are yellow.

Based on the research outlined in sections 2,3 and 4 geology, hydrogeology, rivers, vegetation, land use, soil and slope were selected as evidential themes and tested for spatial correlation to the archaeological sites of the three training themes**.** In the WoE method, evidential themes comprise integer rasters' of two or more classes. A brief overview of the evidential themes is useful at this stage.

Geology: The underlying geology of the study area has been considered to influence BA settlement and socioeconomics for decades. Borrowing from geology, archaeologists have organised Cypriot valleys into lowlands, midlands and uplands and used characteristics of these formations to discuss and explain settlement patterning, socioeconomics, and political organisation (Keswani 1993; Knapp 2013; Andreou 2016), subsistence strategies (Andreou 2016), defensibility (Catling 1962), resource exploitation (Keswani 1993; Smith 2012; Knapp 2013) among other aspects of past society. This study is particularly interested geology for its influence on BA cultivation, specifically chemical composition (fertility) and mechanics of soils (drainage, erosion, and consolidation) but also for the types of natural resources available at the time (i.e., copper) (Figure 13).

Technical details: the geology data was acquired as a shapefile from the Dept. of Lands and Surveys-Government of Cyprus. The original analog source map scale is 1:250,000. This shapefile was converted to raster and from from floating point to integer using 'Int' (Spatial Analyst) after rounding in raster calculator "Int(G1 + 0.5)" to meet requirements of WoE modelling.

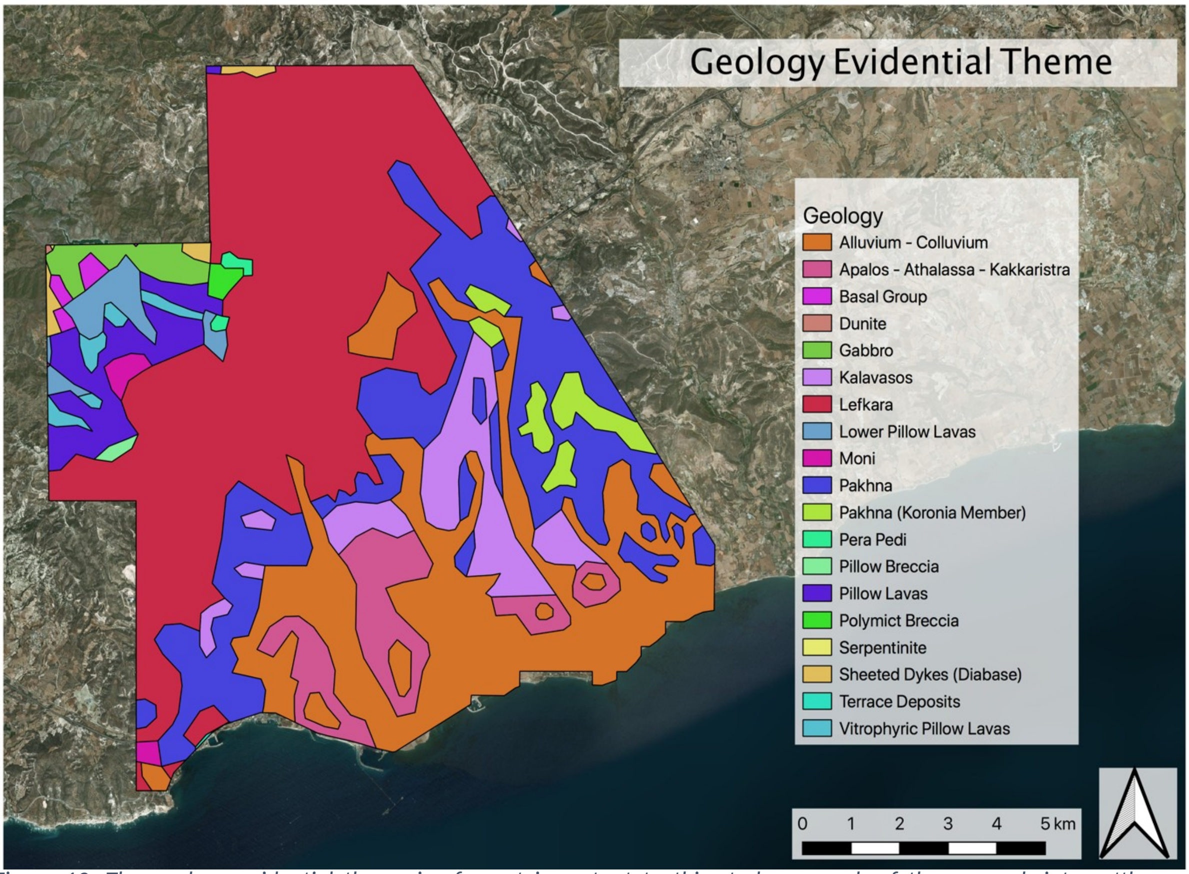


Figure 13: The geology evidential theme is of great important to this study as much of the research into settlement patterning and socioeconomics of the Bronze Age in this area concerns the geological zones of the valley, particularly the Lowlands (notably Alluvium, Pakhna, Apalos-Athalassa-Kakkaristra, Kalavasos) and midlands (notably Lefkara, various Pillow lavas). The geology profile was surveyed and digitized by the Dept of lands and Surveys, Govt of Cyprus. Base map from Google Earth, https://earth.google.com/web/

Hydrogeology: Potable water is an essential requirement of human survival. We use it to maintain our biological system, to cultivate food, in craft production, for transportation and in many pursuits both essential and recreational. At a minimum, each inhabitant of the Vasilikos and Ayios Minas valleys would require ~7 liters of water per day, depending on their level of activity, to avoid dehydration (World Health Organisation). In a small site of 5-10 individuals, this amounts to acquiring ~10-70kg of water per day, a figure that given their occupation as labor intensive farmers in an arid environment would tend toward the higher end of this range. Add to this, any additional requirements for cooking, ceramic and textile production, garden plot cultivation and you have a significant preoccupation with acquiring fresh water. The Vasilikos and Ayios Minas River valleys lack access to well distributed and permanent potable surface water. Mapping spatial correlation between sites and the hydrogeology of the valleys can help us understand how BA farmers made use of the distribution and movement of groundwater including water table concentrations and more substantial freshwater springs. This layer may prove too coarse in spatial resolution, however statistical verification of this is required to rule it out (Figure 14).

Technical details: hydrogeology shapefile acquired from the Dept. of Lands and Surveys- Government of Cyprus. Original analog source map scale is 1:250,000. This shapefile was converted to raster and from from floating point to integer using 'Int' (Spatial Analyst) after rounding in raster calculator "Int(G1 + 0.5)" to meet requirements of WoE modelling.

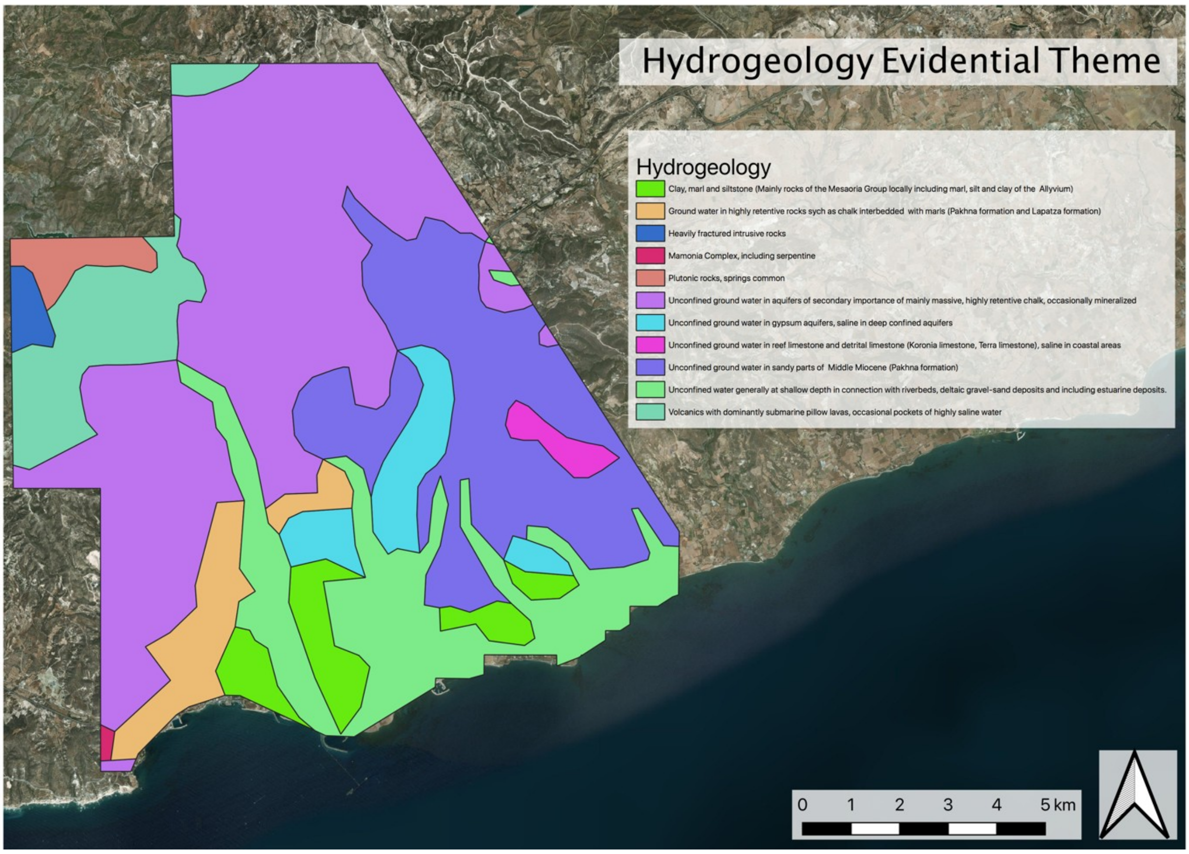


Figure 14: Hydrogeology of the areas of interest. This map may prove too coarse in spatial resolution, but requires statistical verification of this, particularly determining spatial autocorrelation. Base map from Google Earth, https://earth.google.com/web

Rivers: While the hydrogeology map indicates river catchments, springs and other forms of subsurface water supply, it is useful to consider surface water, despite its scarcity. In this map, main courses are favored over tributaries as in the Mediterranean, the latter are undependable due to the rapid evaporation, water table percolation and meandering. While humans have been observed to shift their settlement patterns along and away from less reliable tributaries in response to rainfall frequency (Tainter 1971), it is difficult to know how often this would have been possible and we moreover lack the data to know where these tributaries were thousands of years ago. We have a better idea of where the main river courses ran (Figure 15). The map contains a 1km buffer of these main courses to represent the distance that could be covered in a ~30 minute round-trip to for the purpose of collecting and carrying fresh water. This buffer considers both the weight requirements per day (see above) and rough terrain characterising the valleys. In addition to water reservoirs, rivers can also serve as important transportation routes and while this has yet to be corroborated in the study area, analogs suggest that it is possible that barges may have been used along wider segments for the transport of cumbersome loads such as raw or semi-processed copper (Manning and de Mita, 1997) or perhaps olive oil.

Technical details: The river layer was acquired as a shapefile from the Dept. of Lands and Surveys-Government of Cyprus. Original analog source map scale is 1:100,000. A 1km buffer was created around the main river courses (excluding tributaries). The buffer zone shapefile was converted to raster and from floating point to integer using 'Int' (Spatial Analyst) after rounding in raster calculator "Int(G1 + 0.5)" to meet requirements of WoE modeling.

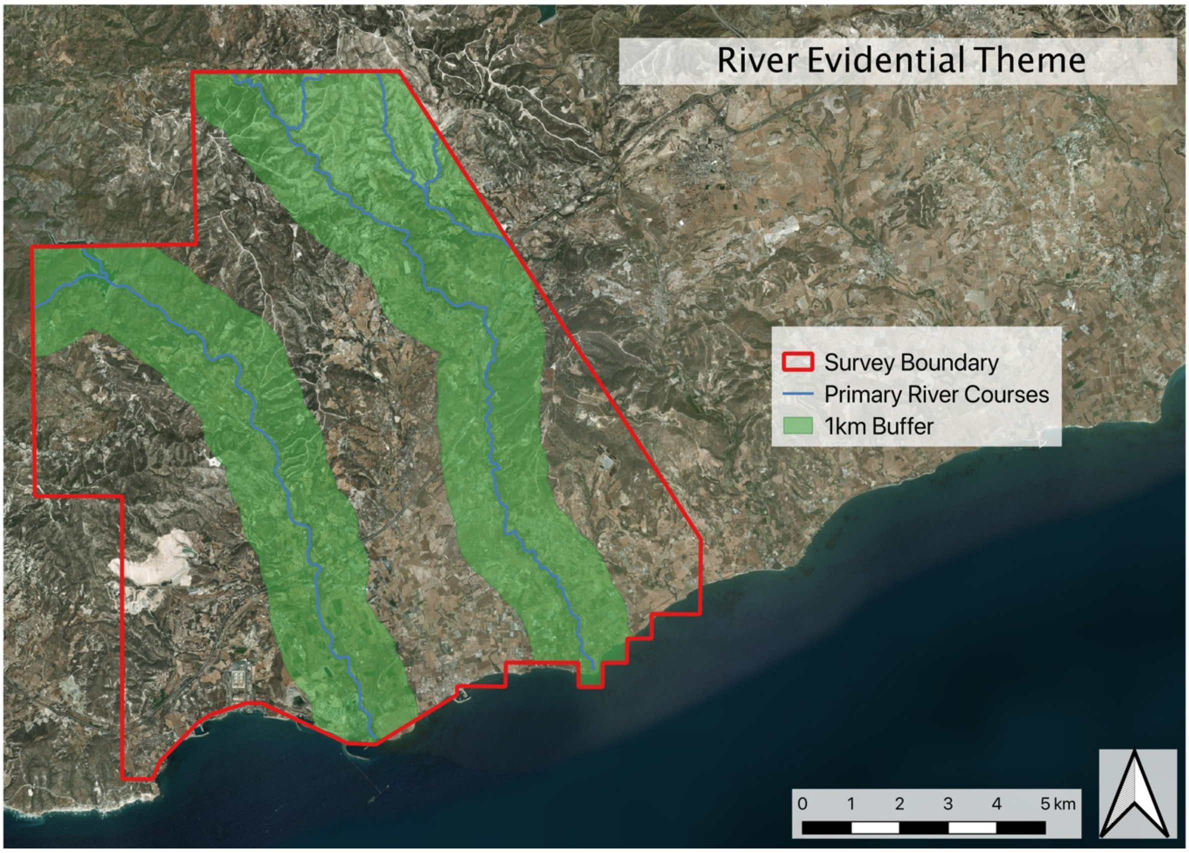


Figure 15: Major rivers in area of interest. Branches from the main tributaries were excluded as they meander, evaporate and are highly seasonal. A 1km buffer was used to indicate reasonable proximity (30min round trip) given the weight requirements and terrain constraints of the valleys. Base map from Google Earth, https://earth.google.com/web/

Modern Vegetation: Present day vegetation patterning can serve as a proxy for fertility of soil and a general indicator of where advantageous soil, geology and subsurface water profiles converge (Roman et al. 2017) (Figure 16). For example, the citrus groves and vineyards of the northernmost portion of the Ayios Minas that exist today demonstrate the area is amenable to productive terrac-based cultivation, a method that is suspected to have been in considerable use during the BA. Modern vegetation cover can also indicate where vegetation cover either obscures or highlights archaeological remains (Merola et al. 2006). This knowledge can help explain why areas that should contain sites are have failed to yield them and inform future ground-truth survey expeditions of this relationship.

Technical details: The vegetation landcover layer was acquired as a shapefile from the Dept. of Lands and Surveys-Government of Cyprus. Original analog source map scale is

1:250,000. This shapefile was converted to raster and from from floating point to integer using ‘Int’ (Spatial Analyst) after rounding in raster calculator “Int(G1 + 0.5)” to meet requirements of WoE modelling.

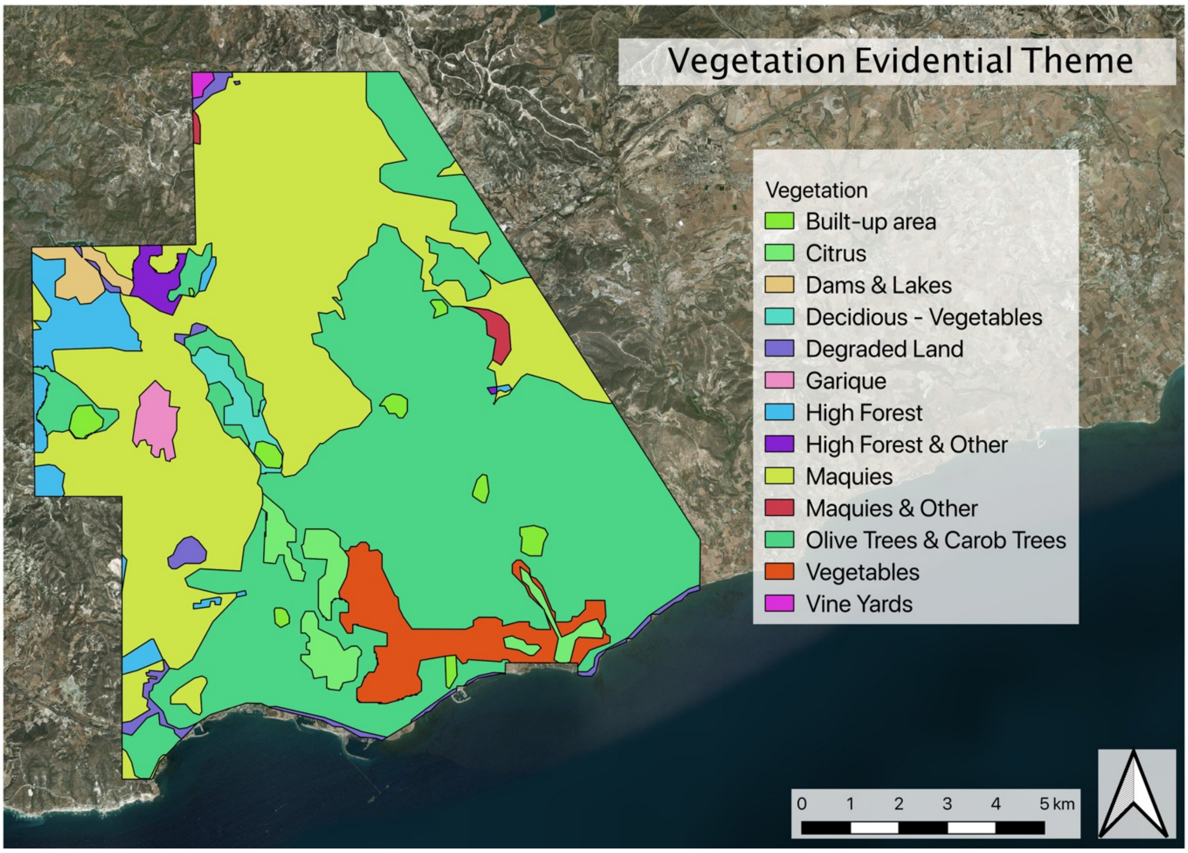


Figure 16: Vegetation profile in the area of interest. Note there re areas of cultivation in this map that would not be so easily inferred to exist in the geology and soil maps, for example the citrus groves in the middle Ayios Minas valley in the northeast in the northeast and the vineyards in the very far north of the areas of interest. Base map from Google Earth, https://earth.google.com/web/

Land use: The land use layer containing agricultural areas, artificial surfaces, forest/semi-natural areas, and waterbodies is another useful resource for understanding present-day archaeological visibility and planning ground-based survey as well as comparing and prehistoric farmers land preferences for settlement, resource exploitation and cultivation to those of the modern era. This map (Figure 17) depicts the more general CORINE Level 1 nomenclature as this study is concerned with differentiating agricultural, artificial (built-up) and forested areas in general rather than their more detailed sub-categorisations. For example, it is sufficient to say that it is forested areas (lv. 1) that limit archaeological visibility than whether the trees are coniferous or transitional woodland (lv.2).

Technical details: The modern land use layer was acquired from the Corine Landcover Inventory of earth observation satellite images. The scale of the dataset is 1:100,000 to facilitate the detection of essential features of the terrain by means of satellite images (Spot, Landsat MSS, TM and IRS) and their representation. This shapefile was converted to raster and from floating point to integer using ‘Int’ (Spatial Analyst) after rounding in raster calculator “Int(G1 + 0.5)” to meet requirements of WoE modeling.

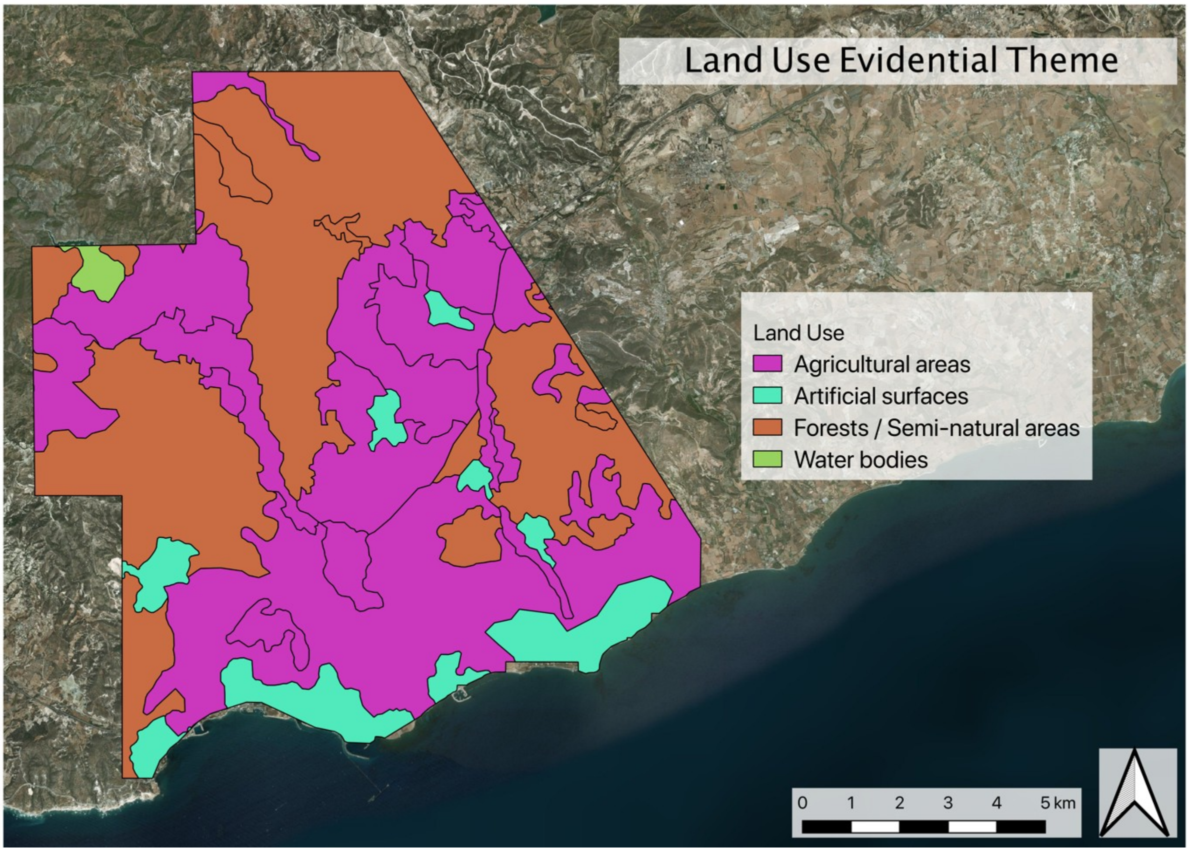


Figure 17: Land use profile of the area of interest. This map uses the more generalised Level 1 CORINE designators as they are sufficient for the aims of the study . Base map from Google Earth, https://earth.google.com/web/

Soil: Along with potable water supply, the chemistry and mechanical properties of soil may be the most influential natural environmental factors for the spatial distribution of cultivation and settlement (Halstead 1987; Bintliff 2011; Farinetti 2011 cf. van Joolen 2003; Halstead and Isakkidou 2011; Andreou 2016). Research into the fertility, and perhaps more importantly the workability of soils and their proximity to other resources have allowed archaeologists to provide more sophisticated explanations for the movements of people over the course of the BA, particularly the move from the midlands proper to the fringes of the lowlands during the early part of the late BA (Andreou 2016). While the valleys contain the same types of soils, it is the differences in their distribution and relative abundances that hint that settlement and cultivation patterns were probably different between them. (Figure 18).

Technical details: the soil layer was acquired as a shapefile from the Dept. of Lands and Surveys-Government of Cyprus. Original analog source map scale is 1:250,000. This shapefile was converted to raster and from floating point to integer using ‘Int’ (Spatial Analyst) after rounding in raster calculator “Int(G1 + 0.5)” to meet requirements of WoE modeling.

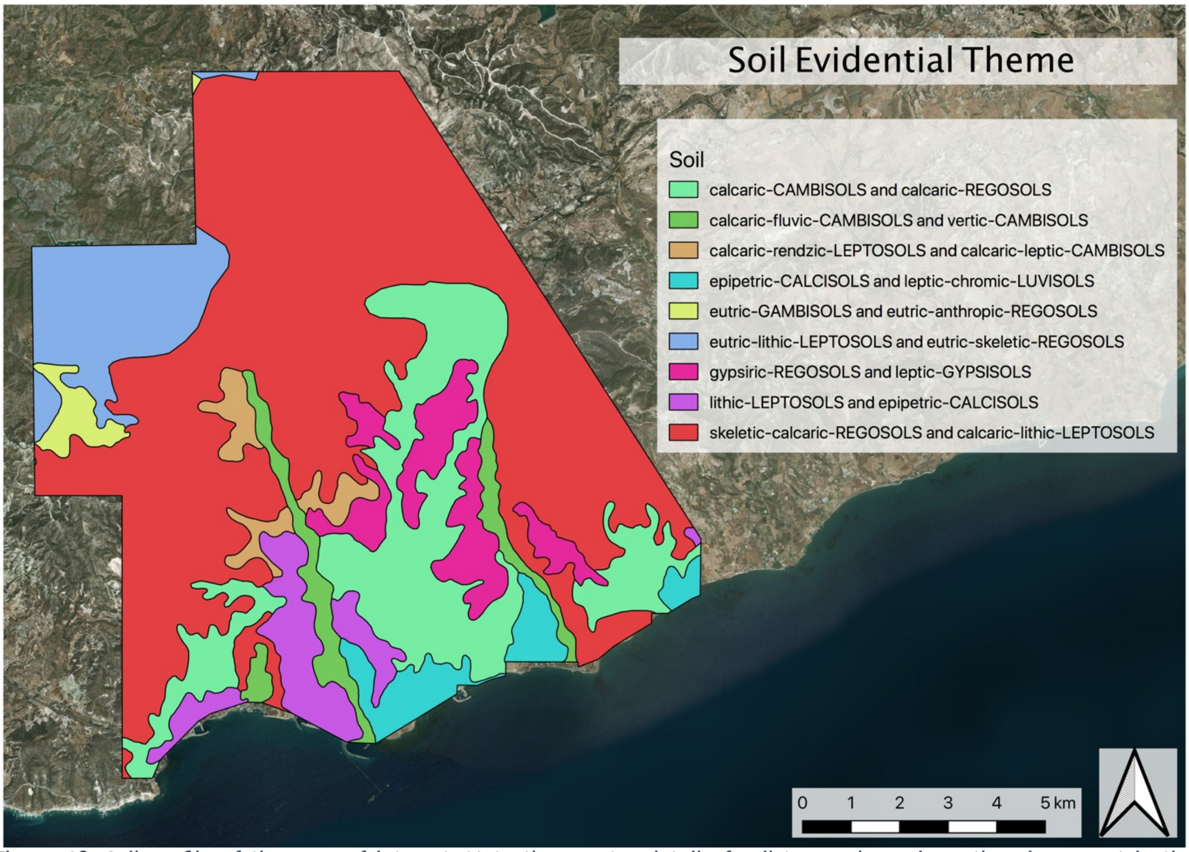


Figure 18: Soil profile of the area of interest. Note the greater detail of soil types along rivers than is present in the geological map, but also the generalisation of the midland chalk plateaus that is broken down in to regional variants in the geology map. These two maps should be used together when considering settlement patterning. Base map from Google Earth, https://earth.google.com/web/

Slope: Slope is perhaps the most widely used evidential theme in predictive modeling as it has proven to be a near universal factor for influencing site location (Dalla Bona 2000; Duncan and Beckman 2000; Kvamme 1985). Settling on areas of low slope reduces the energy required to build structures and manage moisture loss in agricultural soils (Galletti, et al. 2013:50). The hypothesis is that prehistoric people preferred to settle on areas of low slope to such an extent that the mean slope of archaeological sites should be far lower than that of a set of randomly distributed sites. While extremely low sloped terrain is favorable for settlement, BA farmers did farm higher sloped areas in the midlands using the technology of terracing. Most interesting will be to determine whether there is a clear movement from the higher sloped midlands to lower sloped lowlands over the course of the BA as is suggested in current explanatory theories. Whether this shift was wholesale, partial or was perhaps inconsistent across the two valleys and over time will help explain how settlement patterning and socioeconomic development unfolded throughout the BA in the study area.

Technical details: The digital elevation model used to create the slope layer was acquired as a raster file from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) dataset. The spatial resolution is 1 arc-second, or approximately 30 meters. The slope raster was created from an ASTER-GDEM2 digital elevation model for southeast Cyprus expressed in degrees of vertical incline/decline. The slope layer was created using the 'Slope' tool in the 'Spatial Analyst' toolkit by calculating the maximum rate of change in value from that cell to its neighbors and by taking the maximum change in elevation over the distance between the cell and its eight adjacent cells as the steepest downhill descent from the cell (Burrough and McDonell 1998: 190). Cell size is $10m^2$. The slope raster was converted from floating point to integer using 'Int' (Spatial Analyst) after rounding in raster calculator "Int(G1 + 0.5)" for WoE modeling and displayed in increments of 20 degrees (Figure 19).

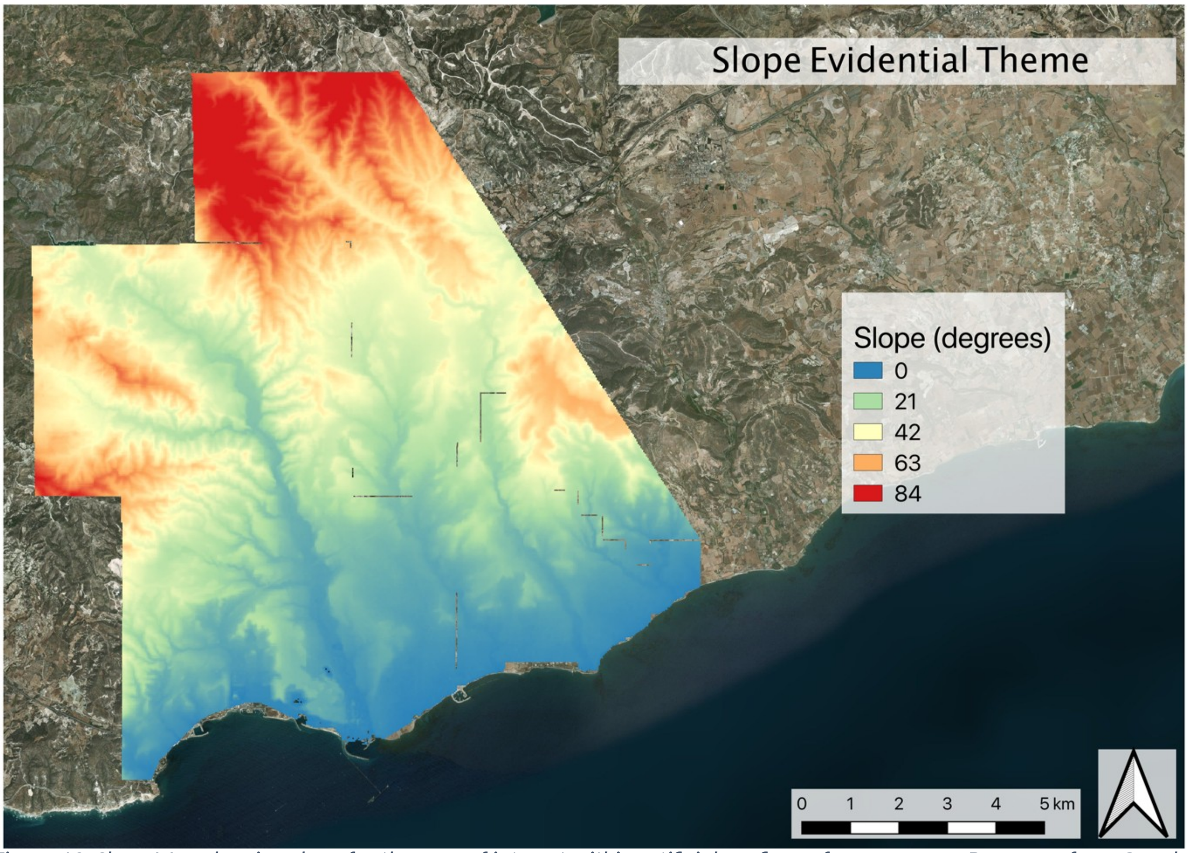


Figure 19: Slope Map showing slope for the area of interest within artificial confines of survey areas. Base map from Google Earth, https://earth.google.com/web/

Please see table B: Environmental Data Set in appendix A for further raw data and processing details for evidential theme layers.

5.1.2 Step 2: Layer Generalisation: Calculate Weights and Reclassify Evidential Themes

Before a sensitivity map can be produced, evidential theme rasters' are subjected to a two-stage process of "generalisation" that includes:

i. Calculating weights: each class of each evidential theme is assigned a value that expresses the strength of its spatial association to the points of the training theme.

ii. Reclassification: the values resulting from the calculation of weights are used to assign each class of each evidential theme to either a presence or absence category, reflecting whether they are positively or negatively associated with the points of the training theme. This process creates binary evidential themes.

Calculate Weights
Overall, the calculate weights stage provides an indication of how important an evidential theme is to the entire model. Calculate weights is accomplished using the 'Calculate Weights' tool in the ArcSDM toolset. In models where the evidential layers are generalised into binary classes, as is the case with this study, the weight added is either W+ (binary pattern present) or W- (binary pattern absent). The variances of the weights enable the calculation of an uncertainty map. The strength of association between the input map and the known archaeological sites is referred to as the contrast (C), which equals W+ - W-. The significance of C can be tested by estimating sigma C and is presented as a studentised contrast, or Stud(C). The weights themselves are calculated as log ratios of conditional probabilities (Bonham-Carter et al. 1989). Finally, capture efficiency and the observed-expected (OE) ratio are also calculated (Sawatzky et al. 2004) and help the modeller adjust and select the most appropriate groupings or thresholds of classes within an evidential theme raster for reclassification in preparation for creating the multi-map signature in the final response raster.

Ideally, the modeller seeks to maximize the contrast, capture efficiency and OE values, while ensuring that the studentized contrast is within an acceptable range (Ford and Hart 2009). An acceptable range is determined by the modeller, with some (i.e., Peters and Partington 2008) using several levels of studentized contrast values, in conjunction with C values, when inferring the strength of spatial correlations. Raines (2001) reminds the archaeologist to continually ask themselves whether their decisions (i.e., groupings and re-classifications) make sense within the archaeological context.

The inputs for the "Calculate Weights" tool for each evidential theme include:

- Type of weight: **categorical (**as all evidential themes used in this model are distinguished by discrete types, not continuous);
- Unit area: **0.00001** (10m, see section 5.2 for reasoning); and
- Confidence level of studentised contrast: **2, or ~98%** (2 out of every 100 times, the sampling experiment will have a false estimate of population parameter with a ± error, this is a very high accuracy standard).

Please see tables F-Z in Appendix B for the weights and confidences for the classes of each evidential theme for the ALL-chronological periods, EBA/MBA and LBA models.

Reclassify Evidential Themes
Choosing whether to reclassify in binary (presence/absence, e.g., Honarvar et al. 2006) or extended multi-class based on the results of the calculation of weights is not straightforward. Some have argued that multi-class layers have been found to provide better prediction rates and more finely differentiated posterior probabilities (Porwal et al. 2003); however, many modelers use binary predictor layers, because conditional dependence and the risk of over-fitting may increase because of using multi-class layers (Raines 2010). Raines (2010) has stated that a good selection of training sites is likely more important than the use of multi-class evidence.

To reclassify, the modeler must determine the maximum contrast threshold of each class of each evidential theme. Values between 0 and 0.5 are weakly predictive; between 0.5 and

1.0 are moderately predictive, and values greater than 1.0 are strongly predictive (Rosenthal et al. 2003). This model employs binary reclassification into “site present” and “site absent” according to the following criteria:

(1) The “site present” group is created from classes of highest contrast and, following advice from Rosenthal et al. (2003) that if no combination of classes of a particular evidential theme could be grouped such that the contrast is at least 1.0 is reached, then the entire theme should be rejected.

At this stage, the river layer was rejected. No attempt was made to adjust the buffer distance and re-calculate weights as it is believed that the unpredictable and turbulent nature of the rivers as well as large and steep banks made nearby settlement unreliable and dangerous. Moreover, to reach a satisfactory contrast, the buffer of rivers in the layer would have had to be extended to a distance as to prevent meaningful statistical discrimination of presence/absence. Essentially the entire map becomes populated with presence pixels.

(2) So long as criteria for maximum contrast threshold are met, the evidential theme will be reclassified to contain the greatest number of training sites in the smallest area.

(3) If the contrast curve contains too much statistical noise and factors unrelated to physical processes, then more complex interpretations, adoption of multiple classes or discard of those evidential themes may be necessary.

5.1.3 Step 3: Conditional Independence Testing of Evidential Themes

The WoE method assumes conditional independence (CI) among evidential themes, i.e., that the presence of a pattern in one is not influenced by the presence or absence of patterns in others (Bonham-Carter 1994; Agterberg and Cheng 2002) as CI can inflate or sometimes deflate the posterior probability values. In archaeological predictive survey, CI is often impossible because patterns are chosen based on their empirical or theoretical spatial relationships with archaeological sites, and these patterns are often dependent on the same underlying geology. Additional patterns typically introduce related evidence and as a result, decrease CI. Raines (2006; 2000; 1999) suggests that where CI cannot be eliminated or acceptably reduced, the results of posterior probability should only serve to generate an ordinal ranking system from “Unlikely” (least likely to host an archaeological site) to “Favourable” (most likely to host an archaeological site). This project employs the relative ranking system and so CI will not be considered further. Other data-driven modelling methods (i.e., logistic regression) are unaffected by CI and with the same evidential and training themes, logistic regression usually produces ranks that are like those obtained from the WoE method (Wright and Bonham-Carter 1996).

5.1.4 Step 4: Generate Response Raster

Once the evidential themes have been generalised, the prospectivity map can be generated using the ‘Calculate Response raster’ tool. Irrespective of method, in all prospectivity maps each cell represents a unique combination of classes derived from the contributing evidential themes. This is referred to as the “unique condition”. In simpler models, the “unique condition” comprises a background phenomenon that is used only to determine the final measure of predictability. It is in the use of the “unique condition” that the WoE method demonstrates its power over these standard models as it assigns to each cell a value that reflects its “unique condition” and is later referenced when determining the probability that any given cell contains a site, in a phenomenon referred to as “posterior probability”. The logic to create a high-quality sensitivity map follows that each class in each evidential theme is represented by a group of cells containing the same values (See Table 1 as an example of an output table for 3 binary evidential themes, producing a response raster with eight unique conditions).

Unique Condition No.	Area (km^2)	Theme 1	Theme 2	Theme 3
1	101.7	2	2	2
2	56.2	2	2	1
3	142.1	2	1	1
4	17.0	1	2	2
5	29.8	1	1	2
6	229.3	1	2	1
7	171.2	2	1	2
8	3.8	1	1	1

Table 1: Unique condition table for three binary evidential themes. Values under theme columns refer to site Present = 2, site Absent = 1. These are hypothetical figures for illustrative purposes.

Once the response raster is generated, an area frequency table is calculated using the "Area Frequency Table" tool in ArcSDM. Plotting the RASTERVALU and CAPP_Cumulative columns found in this table on the Y and X axes respectively provides a cumulative area-posterior probability curve (CAPP). The natural breaks in this curve correspond to prediction thresholds and provides guidance on classifying the cells of the response raster. In the case of this study, a tripartite categorisation comprising "Not Permissive", "Permissive" and "Favourable" for archaeological significance is adopted. (Sawatzky et al. 2009).

5.2 Recommended Steps for WoE Predictive Modelling

5.2.1 Step 5: Cross-validation: Model Data Performance & Kvamme's Gain Statistic

The power, synonymous with utility of a predictive model is dependent upon the accuracy and precision of its data; wherein accuracy is the percentage of points accurately predicted and precision is the proportion of the study area that is covered by that class. Each metric alone is insufficient to assess the power of a response raster because a class that covers the entire area will be perfectly accurate but of little predictive power while a class covering a single raster cell that contains 1 point will be perfectly precise but performs poorly as a predictor overall. A useful measure of a Response rasters' power, that is the raster produced by the WoE method, is Kvamme's (1988) Gain Statistic (KGS) as it measures the gain in effectiveness of that response raster over a completely random model of no predictive capacity.

The KGS formula is expressed as:

$$Gain = 1 - \left(\frac{PA}{PS}\right)$$

PA = percentage of total area covered by a class within the response raster.

PS = percentage of total sites within that class.

Kvamme (1988: 329) indicates that positive results suggest some gain over a completely random model with values approaching 1.0 possessing ever increasing predictive utility and negative values possessing reverse predictive utility. The value threshold of high performing is debated. In a multi-model review by Verhagen (2007) he found that KGS values ranging from 0.5 to 0.8 were considered high performing but expressed doubt as to whether high gains were possible by most models. Many models tend to focus on assessing the KGS values of the two highest sensitivity classes of a given theme as lower classes tend to fail to meet cut-off values. This approach is used in this study.

Verhagen (2007) has suggested that gain statistic of >0.6 appears to indicate a high performing model, however he notes that "the use of medium probability zones poses an additional problem for model performance assessment as these are zones of no predictive power, they mainly serve to minimize the zones of high and low probability. The gain of the high and low probability zone then, will always be inflated and will not give a good impression of the performance of the whole model - in the end, we are not particularly interested in a model where most of the study area is medium probability." (Verhagen 2007, p135). Models then, should strive to keep the share of the 'medium' range as small as possible (van Leusen 2009).

5.2.2 Step 6: Ranking Areas of Archaeological Potential for Ground Survey
Following the validation of the response raster, the areas of notable archaeological potential can be used in several ways to inform further action. Two common applications are archaeological ground-survey and commercial archaeological investigation ahead of development. To approach the first of these in an efficient and economical way, the areas of interest (AoI) appearing in the response raster should be priority ranked. There is no clear quantitative methodology for ranking archaeologically significant areas (Carranza 2009) as it is often a subjective case-by-case exercise concerning the relationship between site location, prior research, environmental conditions, and past and present cultural values.

In this study, the areas (comprised of raster cells) of “permissible” and “favourable” archaeological sensitivity are converted to polygons. Six criteria are used to assign a rank value to each polygon and that with the highest rank will be ground surveyed. While not rigid, criterion 1, 2, 3 and 6 are weighted highest. The full set of criteria include:

1) **Low known site density:** polygons containing a low density of known sites are favoured over polygons containing a higher density of known sites. A low number of known archaeological sites is favored as we rarely know the spatial extent of known sites and it is probable that “permissible” and “favorable” pixels adjacent and near known sites likely belong to those sites rather than indicate totally new and previously unidentified sites. While these pixels can help determine the actual site extents of known sites, the aim of this study is to locate new sites in archaeologically favorable areas.

2) **Accessibility:** polygons that possess lower barriers to walkover survey are favored. This includes areas of low slope, low vegetation density, road access, low development, and lack of legal access restrictions (non-militarised, commercial, etc.).

3) **Soil/Cultivation characteristics:** the type of soils present in polygons and their implications for cultivation practices in the past are factored in to ranking. For example, regosols and leptosols are sometimes used for ‘capital intensive’ (high-input and high-financial gain) irrigated farming but primarily are used for low volume grazing and are amenable to terrace cultivation. Cambisols by contrast are more fertile but require draught animals and specialized ploughs largely unavailable in the early to middle BA. These soil types have different likelihoods of containing archaeological material related to settlement.

4) **Geology:** The surface and subsurface geology of polygons including slope, presence of a major river course, bedrock and water retention have important implications for archaeological settlement and viability.

5) **Modern Landcover/use:** how the land is used today not only says something about its potential for settlement in the past (i.e., modern cultivation practices) but can help us understand site visibility and access in the present (i.e., modern urban development).

6) **Degree of Archaeological Knowledge:** prior research is essential to understanding the archaeological potential of a particular polygon. For example, polygons indicating areas potentially containing previously unidentified sites residing in the VVP and MVASP survey areas may have been investigated, overlooked, or set aside for future investigation may be referred to in documentation that can inform ranking. A good example of this is the north-western area of the VVP area that was not surveyed but was nevertheless considered promising by Todd (2013), the project director.

5.2.3 Step 7: Ground Survey

While not a required step in the predictive survey methodology, ground-truth field work is the best means of verifying predictive model results. In addition to considering the results of ranking, an account of time, personnel, financial and other resources should be made if there is intention to visit a particular polygon. As walkover survey personnel are limited to the author and any survey must be conducted over a maximum of 5 working days, the area should be confined to ~5km^2 based on the requirements of previous campaigns in the area. Details are discussed below in section 7: Results.

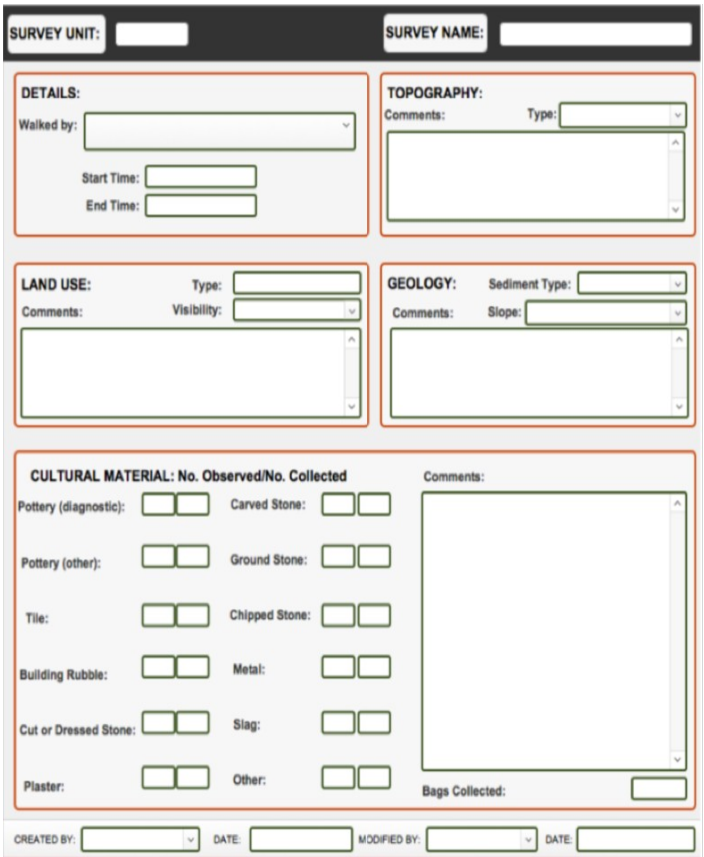


Figure 20: Database general user interface for ground survey.

A digital database was built using FileMaker Pro to record primary and contextual data of any archaeological finds found during walkover survey (Figure 20). The breadcrumb function on a Garmin E-Trex handheld GPS unit was used during walkover survey to track the survey path while "sites" were recorded as shapefile points and a Nikon D3000 DSLR camera was used to capture photographs. This data was exported as two shapefiles (Table 2) and uploaded into ArcGIS for visualisation and analysis, exported as a CSV file and converted into a Microsoft Excel table. A separate photo register was produced using Microsoft Excel for metadata and Windows folder to hold RAW images.

Data Layer	Format	Acquired From	Notes

AMMV Sites (Points)	Recorded as Shapefile (point)	Walkover Field Survey of AMMV	45 sites identified during the AMMV survey and attributed to various chronological periods and spatial extents.
AMMV Survey Paths	Recorded as shapefile (line)	Walkover Field Survey of AMMV	Captured using Garmin E-Trex Handheld GPS. Exported as shape file.

Table 2: Data layers created based on Ayios Minas Middle Valley ground survey.

6 Results: Weights of Evidence Predictive Modelling

6.1 Results of the Weights of Evidence Predictive Modelling Workflow

This section presents the results of the four essential and three optional steps of the WoE predictive modelling methodology outlined above.

6.1.1 Results of the Essential Steps

Step 1. Training Themes

Three models were developed to address the study aims. Model 1 uses a training theme drawn from all known archaeological sites regardless of chronological association with the aim to build a prospectivity map that can be used to guide archaeological survey and modern development. Models 2 and 3 use training themes derived from sites belonging to the early/middle and late BA respectively. The results of these models will help illustrate the change in settlement at this juncture of the BA for the reasons outlined in section 5. The ALL periods training theme is comprised of 50-randomly selected sites. The second and third models are comprised of the entire datasets for their corresponding chronological periods.

Step 2. Generalisation of Evidential Themes

The results of the "Calculate weights" step guides the reclassification of classes in each evidential theme into binary. This binary indicates whether sites are meaningfully present or absent from pixels associated with each class (expressed as values 1 or 0) and is essential preparation for calculating the 'response raster'. The results of this reclassification for the ALL-chronological period, early/middle BA and late BA models are outlined in tables 3, 4 and 5. For the raw output tables of the "Calculate weights" process, please see the tables F to Z in Appendix B.

Evidential Theme	Presence (Classes)	Area (km²)	No. Sites	Absence (Classes)	Area (km²)	No. Sites
Slope	0, 3, 6, 7, 10, 15, 16, 18°	46.2	32	1, 2, 4, 5, 8, 9, 11-14, 17, 19-22, 23, 90°	81.2	18
Vegetation	0, 1, 2, 5, 12	13.6	14	3, 4, 6, 7, 8, 9, 10, 11, 14	113.8	36
Soil	0, 2, 3, 7, 8	22.2	20	1, 4, 5,6, 9	105.2	30
Hydrogeology	1, 2, 7, 10	37.4	32	0, 3, 4, 5, 6, 8, 9, 11	90.0	18
Geology	1, 4, 6, 14, 29	46.4	31	2-3, 5, 7-13,15-28, 30	80.9	19
Landuse	1, 2	62.4	32	1, 3, 5	64.9	18

Table 3: Generalisation of Evidence Themes for Sites from ALL Chronological Periods. Column 1 contains the name of the evidential theme, 2 contains the classes that have a statistically significant presence of archaeological sites, 3 contains the area of that class, 4 the number of sites within those classes while 5,6 and 7 contains the same information for those classes that have a statistically significant absence of sites. These figures are based on the results of the 'calculate weights' step. Recall that the river layer was removed at the weighting stage, prior to reclassification.

Evidential Theme	Presence (Classes)	Area (km²)	No. Sites	Absence (Classes)	Area (km²)	No. Sites
Slope	0-16°	108.0	41	16–90°	19.0	1
Vegetation	1,2,4,5,8,12	16.0	14	0,3,6,7,9,10,11,13	111.0	28
Soil	2,3,8	13.0	18	0,1,4,5,6,7,9	114.0	46
Hydrogeology	1,2,10,11	41.0	28	0,3-9	86.0	14
Geology	1, 4, 6, 29	46.0	26	0,2,7-28,30	81.0	16
Landuse	2	61.0	31	0, 1, 3,5	66.0	11

Table 4: Generalisation of Evidence Themes for Sites from the Early and Middle Bronze Age. Column 1 contains the name of the evidential theme, 2 holds the classes that have a statistically significant presence of archaeological sites, 3 contains the

area of that class, 4 the number of sites within those classes while 5,6 and 7 contains the same information for those classes that have a statistically significant absence of sites. These figures are based on the results of the 'calculate weights' step. Recall that the river layer was removed at the weighting stage, prior to reclassification.

Evidential Theme	Presence (Classes)	Area (km^2)	No. Sites	Absence (Classes)	Area (km^2)	No. Sites
Slope	0-15°	99.0	58	15–90°	28.0	6
Vegetation	1,2,4,5,8,12	15.0	19	0,3,6,7,9,10,11,13	112.0	45
Soil	1,2,3,8	34.0	30	0,4,5,6,7,9	93.0	34
Hydrogeology	1,2,7,10	37.0	36	0,3,4,5,6,8,9,11	90.0	28
Geology	1,4,6,14,16,20,30	46.0	36	0,7,8,9,10,11,12,17,18, 23,24,25,26,28,29	81.0	28
Landuse	0,2,5	63.0	36	1,3	64.0	28

Table 5: Generalisation of Evidence Themes for Sites from the Late Bronze Age. Column 1 contains the name of the evidential theme, 2 holds the classes that have a statistically significant presence of archaeological sites, 3 contains the area of that class, 4 the number of sites within those classes while 5,6 and 7 contains the same information for those classes that have a statistically significant absence of sites. These figures are based on the results of the 'calculate weights' step. Recall that the river layer was removed at the weighting stage, prior to reclassification.

Step 3. Conditional Independence Tests

Conditional independence did not factor in the production of the three models as results were converted to a relative favourability ranking (see Section 5, step 3). However, "test" models (results of which are not presented here), indicated that the hydrogeology map was a source of conditional dependence and could be omitted from future models.

Step 4. Response Raster Generation

The generalization of the evidential themes for each model used to produce the 'response rasters' are generated via the "Calculate Response" tool which assigns to each cell a value that reflect its "unique condition" (section 6 step 4 on the 'unique condition'). This assigned value is referenced when determining the probability that any given cell contains a site, in a phenomenon referred to as "posterior probability". The logic to create a useable sensitivity map follows that the raster be classified by relative posterior probability, that is, each category in each evidential theme is represented by a group of cells containing the same values. The 'response rasters' produced for the ALL-Chronological periods, the early/middle BA and the late BA models are displayed in Figures 22, 24 and 26.

The response rasters then need to be categorised themselves in a way that reflects the degree of probability that a cell might have for containing an archaeological site. This is done by producing area frequency tables for each response raster using the "Area Frequency Table" tool in ArcSDM then plotting the RASTERVALU and CAPP_Cumulative columns on the Y and X axes respectively to construct cumulative area-posterior probability curves (CAPP). The natural breaks in these curves correspond to prediction thresholds and provides guidance on classifying the response raster and transforming them into maps showing "not permissive", "permissive" and "favourable" categories for archaeological sites (Sawatzky et al. 2009). CAPP curves for the ALL-Chronological period, early/middle BA, and late BA response rasters are shown in Figures 21, 23 and 25.

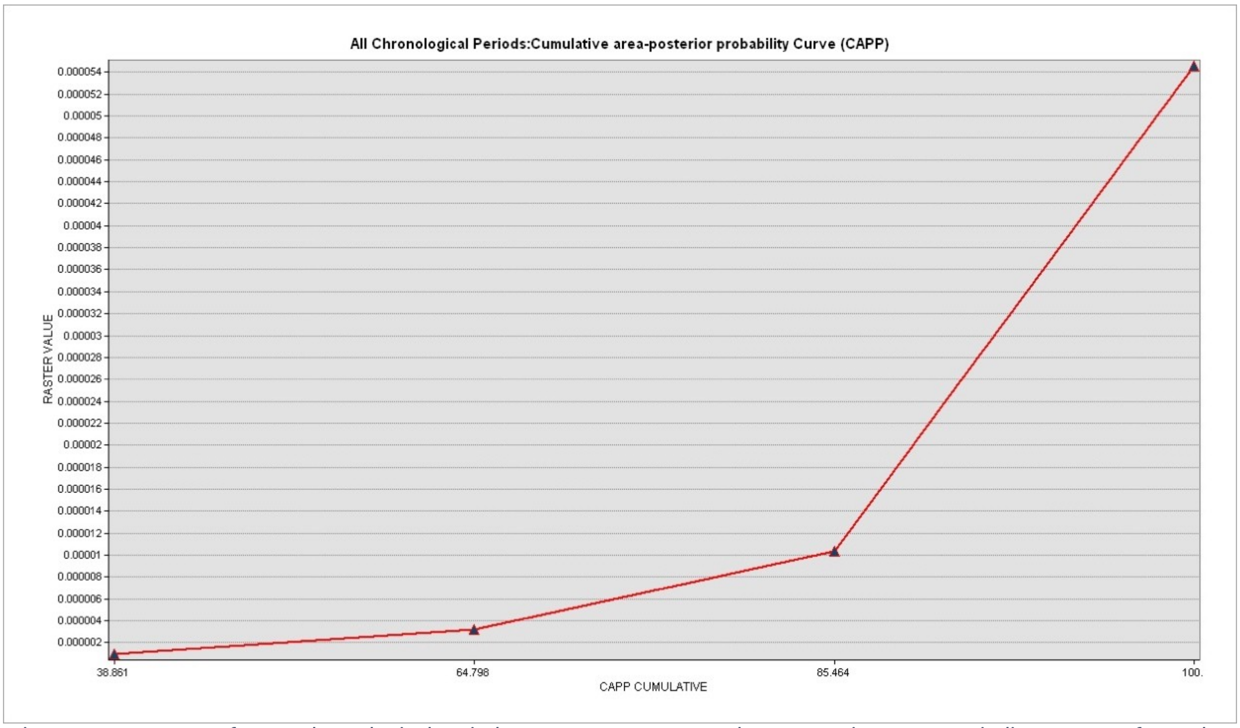


Figure 21: CAPP curve for ALL chronological periods response raster. Areas between points on curve indicate ranges for each category.

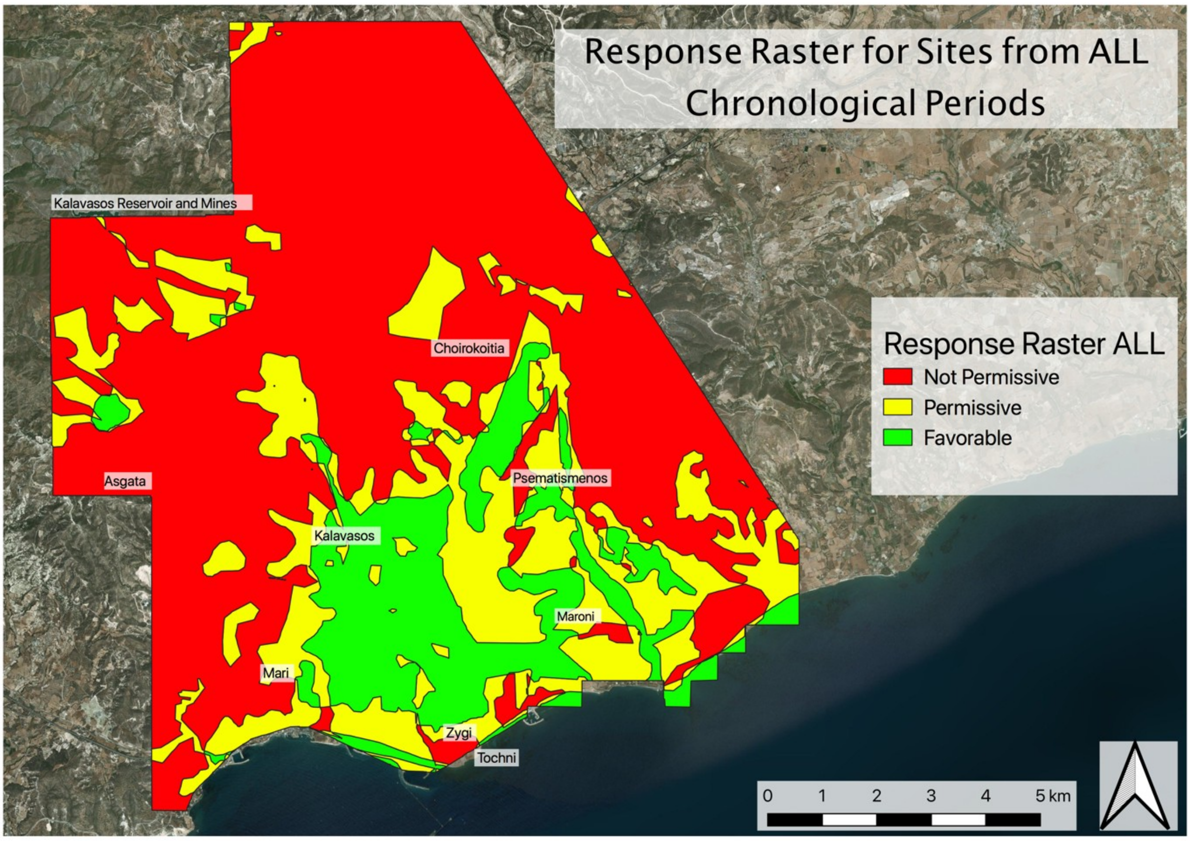


Figure 22: Areas of archaeological potential (sensitivity) are displayed in the Response raster's above for sites from All Chronological Periods. Base map from Google Earth, https://earth.google.com/ web/

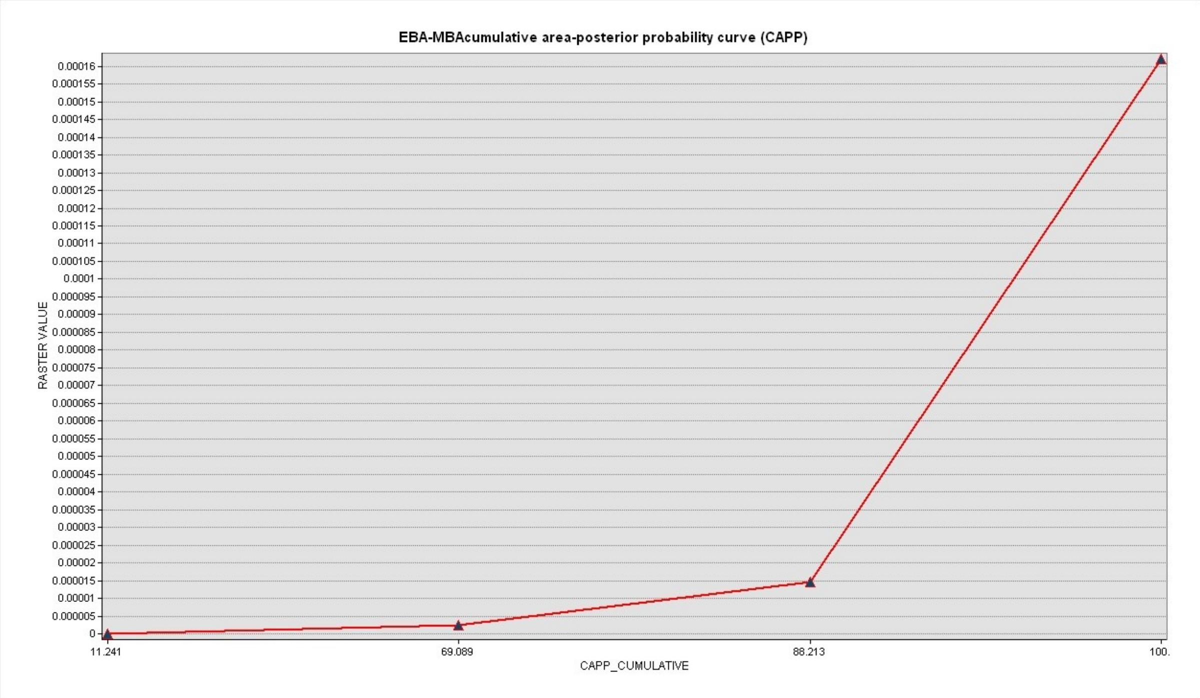


Figure 23: CAPP curve for Early and Middle Bronze Age response raster. Areas between points on curve indicate ranges for each category.

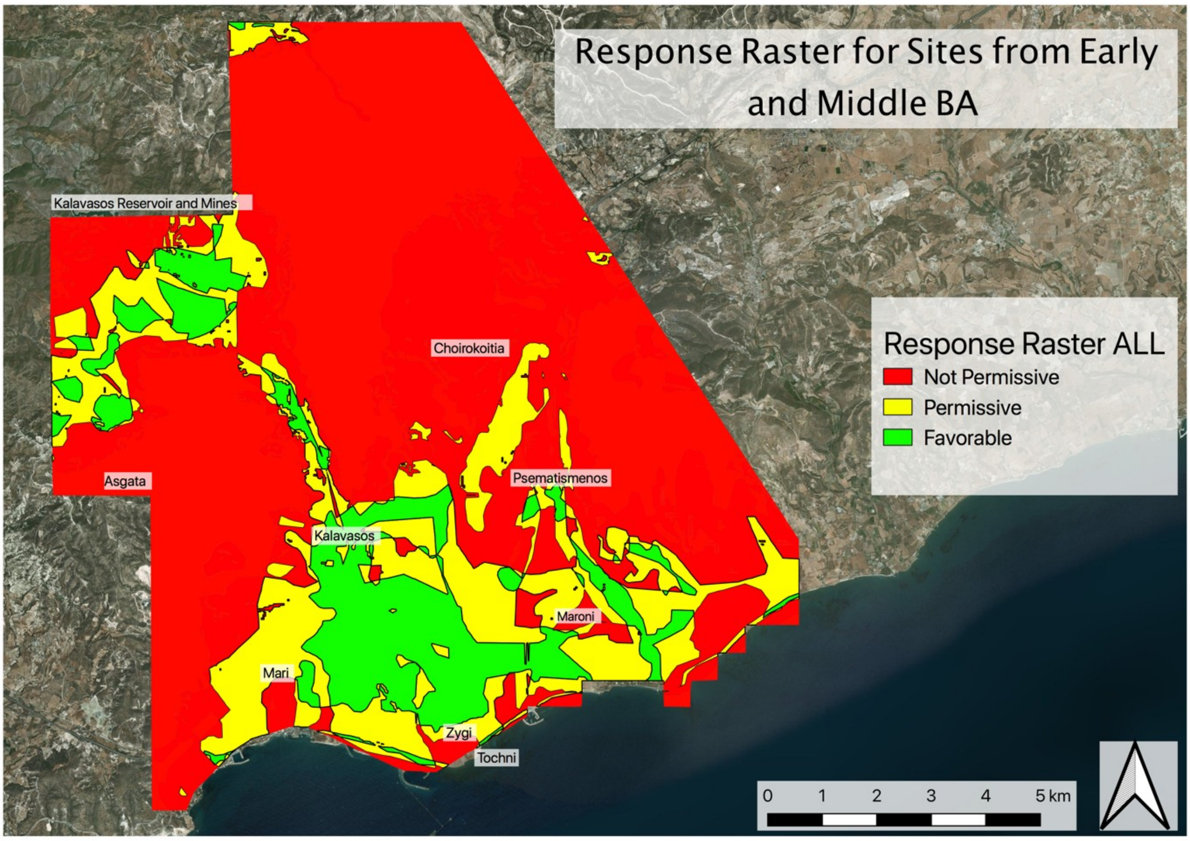
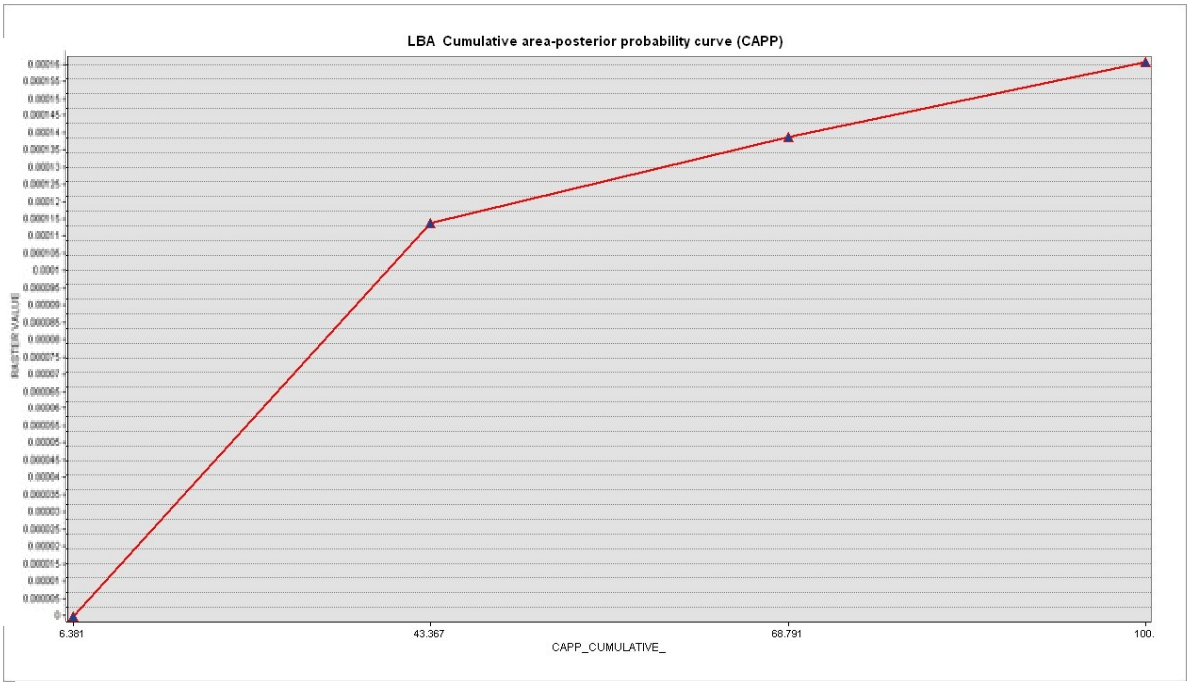
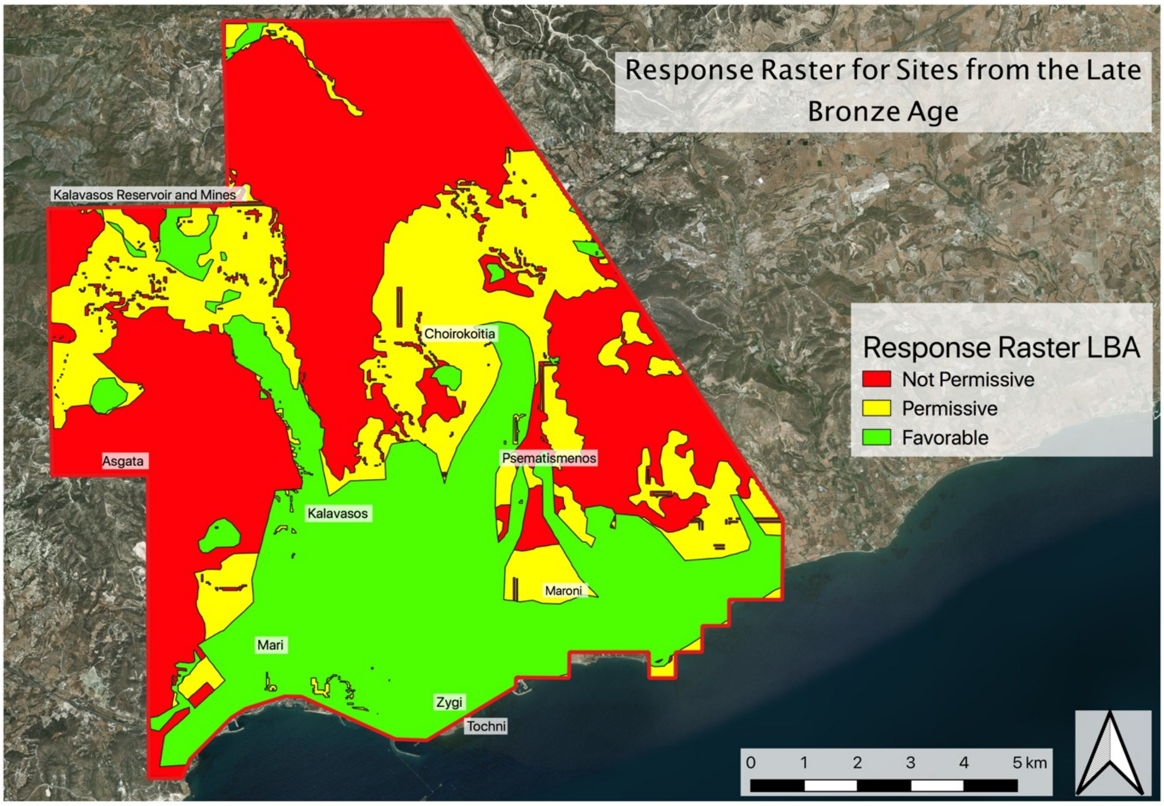


Figure 24: Areas of archaeological potential (sensitivity) are displayed in the Response raster's above for sites from Early and Middle Bronze Age sites. Base map from Google Earth, https://earth.google.com/ web/


LBA Cumulative area-posterior probability curve (CAPP)
RASTER VALUE
CAPP_CUMULATIVE_
6.381
43.367
68.791
100.


Response Raster for Sites from the Late Bronze Age
Response Raster LBA
Not Permissive
Permissive
Favorable
Kalavasos Reservoir and Mines
Choirokoitia
Asgata
Psematismenos
Kalavasos
Maroni
Mari
Zygi
Tochni
0 1 2 3 4 5 km

6.1.2 Results of the Recommended Steps

Step 5. Cross-validation: Model Performance Assessment & Kvamme's Gain Statistic

The three models developed above (ALL chronological periods, early to middle BA and Late BA sites) had the data of their two highest sensitivity classes tested using Kvamme's gain statistic or "KGS"). See section 5, step 5 for an explanation of KGS. The results of KGS are summarised in table 6.

Model	Sensitivity Class	% AREA	% SITES	KGS Value
ALL Sites	2	23	34	0.68
ALL Sites	3	15	36	0.42
EBA and MBA Sites	2	19	26	0.73
EBA and MBA Sites	3	12	48	0.25
LBA Sites	2	25	16	1.56
LBA Sites	3	32	58	0.55

Table 6: Kvamme's Gain Statistic results indicating predictive power of each model. Column 1 contains the model in question, column 2 denotes the class (2 = "permissive" and 3 = "favorable"), column 3 indicates the percentage of total area that the class comprises, column 4 provides the percentage of total sites the class contains and column 5 gives the KGS values. Class 1 is absent as it is recommended that models focus on assessing the KGS values of the two highest sensitivity classes as those lower tend to fail to meet cut-off values.

Verhagen (2007) has suggested that a gain statistic of >0.6 is indicative of a high performing model, however he also notes that "the use of medium probability zones poses an additional problem for model performance assessment as these possess negligible predictive power and mainly serve to minimize the zones of high and low probability. The gain of the high and low probability zone then, will always be inflated and will not give a good impression of the performance of the whole model - in the end, we are not particularly interested in a model where most of the study area is medium probability." (Verhagen 2007: 135). Models then, should strive to keep the share of the 'medium' range as small as possible (van Leusen 2009).

The results of KGS analysis show that the permissive (middle) probability class of All chronological periods, Early/Middle BA and Late BA models are high performing while the favourable probability class of the All-chronological period and Late BA maps perform reasonably well. The favourable probability class of the Early/Middle BA by contrast seems to perform poorly. However, as the medium range of the three maps account for only 19-25% of total area, the models are considered to retain useful predictive power. Future evidence may help to introduce new evidential themes or remove others that may improve performance by shrinking this medium sensitivity zone.

6.2 Summarising the Response Raster Results

The results of validated WoE predictive modeling suggest that archaeological sites regardless of chronological designation are likely to be located where the landscape is:

-≤18 degrees of slope;

-occupying built-up or degraded land, planted with citrus or vegetables;

-comprised of cambisolic, regosolic, gypsisolic, leptosolic and calcisolic soils;

-residing on the alluvium-colluvium, Apalos-Athalassa-Kakkaristra, Kalavassos, Pera Pedi and lower pillow lava geological formations.

Early to middle BA sites are likely to be located where the landscape is:

-≤16 degrees of slope;

-occupying built-up or degraded land, land covered with maquis and high forest or planted with citrus, vegetables;

-comprised of cambisolic, leptosolic or calcisolic soils;

-residing on alluvium/colluvium, the Apalos-Athalassa-Kakkaristra, Kalavassos and pillow lava geological formations.

Late BA sites are likely to be located where the landscape is:

-≤15 degrees of slope;

-occupying built-up or degraded land, covered by high forest or planted with citrus and vegetables;

-comprised of regosolic, leptosolic, calcisolic or cambisolic soils;

-residing on alluvium/colluvium, the Apalos-Athalassa-Kakkaristra, Kalavassos, Pera Pedi, lower pillow lava, Gabbro and Vitrophyric pillow lava geological formations.

The implications of this patterning for supporting, refuting, or encouraging alteration to existing theories of BA settlement patterning and socioeconomics will be discussed in section 7 below.

Step 6: Results of Ranking Areas of Archaeological Potential for Ground Survey.
One of the aims of this study is to identify areas of the study region that should be ground surveyed to mitigate against the destructive effects of modern development another is to test theories concerning settlement patterning and socioeconomics in the Bronze Age. The first aim is addressed by the All-chronological period response raster with some input from the BA response rasters while aim two is approached from the comparison of the two BA response rasters. The “favourable” and to some extent “permissive” classes will inform the creation of a final map that identifies the primary areas of interest for archaeological ground survey and other field works (see Figure 27).

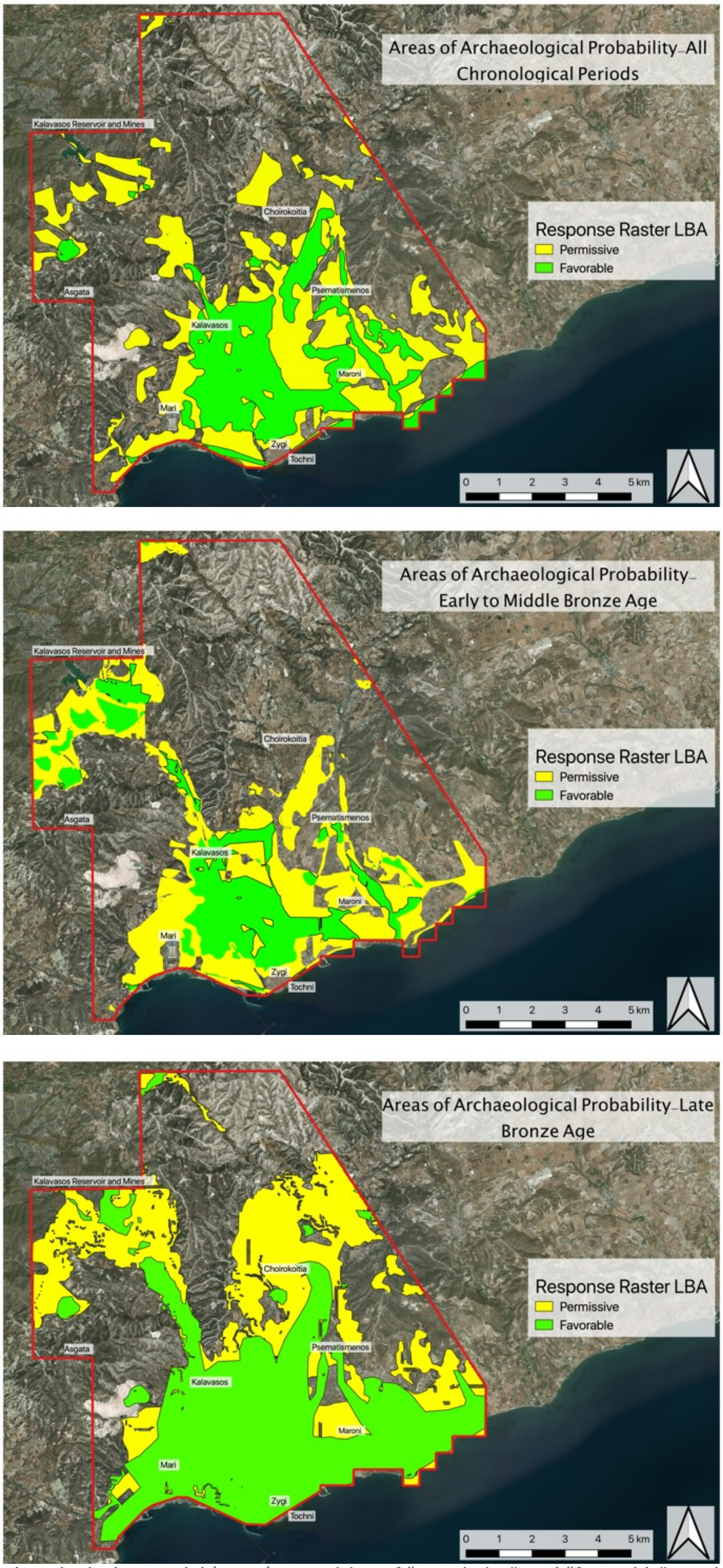


Figure 27: Areas of Archaeological Potential (AoAP) comprising of "permissive" and "favorable" sensitivity areas (classes 2 and 3) for All Chronological Periods (upper), Early to Middle Bronze Age (middle) and Late Bronze Age (bottom). Favorable areas (in green) will be prioritized over "permissive" (in yellow) and will contribute to maps guiding ground survey and theoretical discussion.

6.3 Areas of Archaeological Potential for Ground Survey

Areas of "favourable" and to an extent "permissive" sensitivity within the All-chronological periods' map and in some cases the BA maps, are synthesised into a single map comprising polygons or "areas of interest" (AoI) that will inform the basis of ranking for ground survey (see Figure 28). These areas are ranked according to six criteria: the potential to reveal new archaeological sites (not necessarily extensions of known sites), according to their accessibility as well as based on their underlying soil type and geology, overlying modern landcover and any additional archaeological knowledge/recommendation available in literature or local opinion.

The total area of interest bounded by these polygons' totals 51km^2 (Figure 28). Four of these polygons (1, 3, 4, and 10) comprise 36km^2, or 70.5% of the total area of potential and include 107 of the 144 known sites (74%). This study aims to locate new sites and as a result ground survey should focus on those polygons that WoE predictive survey has identified as archaeologically permissive but that lack known archaeological sites, notably polygons 2, 5, 6, 7, 8 and 9. These polygons comprise 15 km^2 or 29.5% of the total study area and contain only 5% of known sites (7 of 144). The remainder of known archaeological sites (n=30) reside outside of the areas of archaeological potential identified by WoE predictive survey. There is immense utility in studying the polygons that do contain known archaeological sites, particularly for identifying site extents, and these may feature in future research. Table 7 contains the notes on the remaining criteria used to complete the ranking of polygons 2, 5, 6,7,8 and 9.

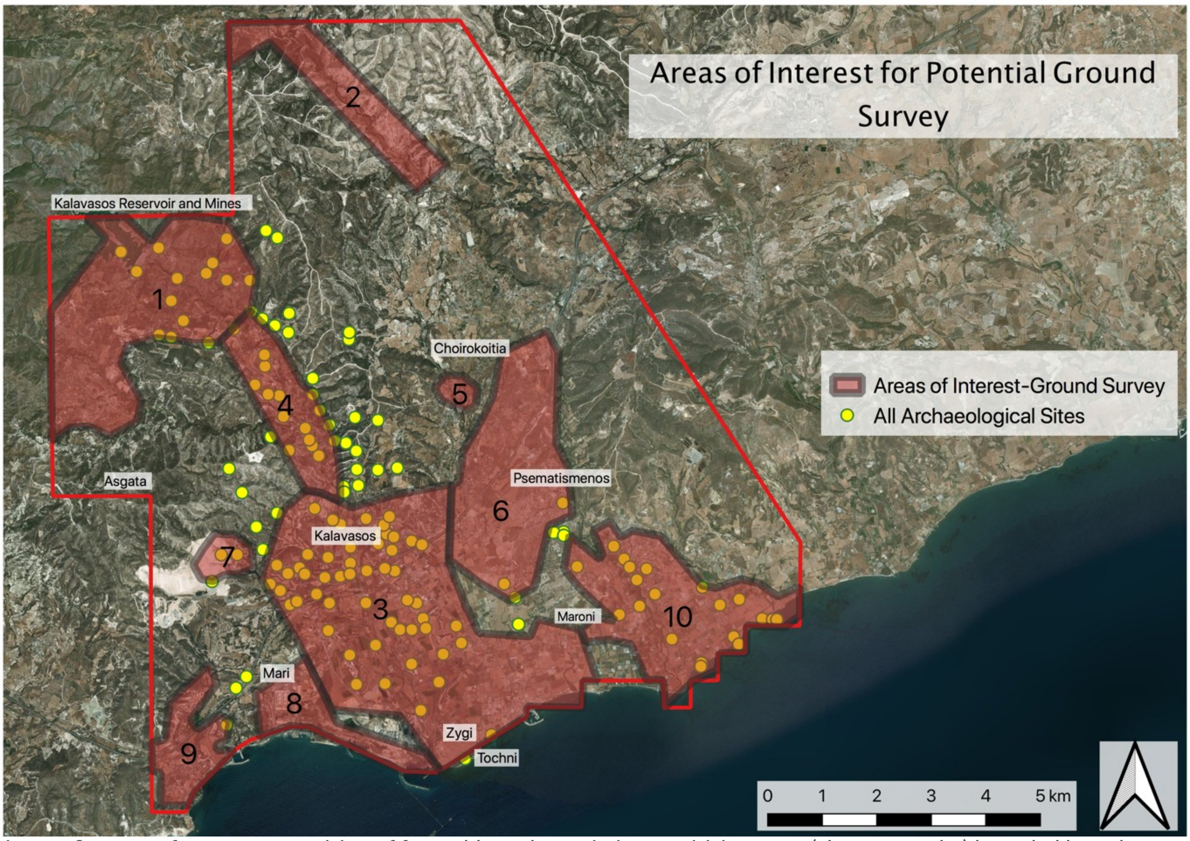


Figure 28: Areas of Interest comprising of favorable and permissive sensitivity areas (classes 3 and 2) bounded by polygons (transparent red) for potential ground-truth survey overlaying recorded sites.

Polygon ID	Other Considerations	Rank
2	Soil/Cultivation: Northern extent of the polygon contains fertile cambisols and regosols that are sometimes used for 'capital intensive' (high-input and high-financial gain) irrigated farming but are primarily used for low volume grazing and are amenable to terrace cultivation. Very stony leptosols and regosols comprise the vast majority of the polygon. Geology: Riverbed and mix of lower riverbed and sharper increase to river bank slopes. Modern Landcover: almost no built-up area, good road access, modern cultivation embedded within forested area. Vineyard in the far north. Degree of Archaeological Knowledge: Ayios Minas Middle valley is almost completely unknown archaeologically and outwith VVP and MVASP. Todd (2013) suggests more intensive survey should be done here.	1
5	Soil/Cultivation: Regosols, leptosols are sometimes used for 'capital intensive' (high-input and high-financial gain) irrigated farming but are primarily used for low volume grazing and are amenable to terrace cultivation. Cambisols are more fertile. Geology: A low slope area along riverbed. Modern Landcover: centered on modern village of Tochni with c. 35% occupied by modern agricultural fields of capital-intensive olive and carob plants, good road access. Degree of Archaeological Knowledge: Ayios Minas Middle valley (area is almost completely unknown archaeologically and outwith VVP and MVASP).	3
6	Soil/Cultivation: Lime-rich fertile cambisols are prominent along the central line of the polygon, however regosols and gypsisols are most common along both flanks of this fertile zone. The regosols and gypsisols are amenable to many cultivars but require terracing to be productive and may also be used for low-volume grazing without any modification. Geology: Ayios Minas River runs through southern extent. Modern Landcover: Modern village of Psematismenos located along central-eastern border. Cultivation extensive (capital-intensive olive and carob) with two areas of forest along eastern border north and south of village. Main powerline runs along the long axis of the polygon. Significant road access but may limit survey in some areas. Degree of Archaeological Knowledge: Approximately 40% of the polygon resides within the MVASP boundary while the remainder falls within the unsurveyed Ayios Minas midlands.	2
7	Soil/Cultivation: Regosols, leptosols and cambisols are sometimes used for 'capital intensive' (high-input and high-financial gain) irrigated farming but are primarily used for low volume grazing and are amenable to terrace cultivation. Geology: Minor branches of Vasilikos river run through the polygon. Gypsum-rich chalk plateau. Modern Landcover: Significant portion of polygon (60%) comprised of a gypsum mine with remainder covered by forest (40%). Degree of Archaeological Knowledge: Lies entirely within the VVP and was surveyed as part of a larger transect.	4
8	Soil/Cultivation: Mixed soil profile containing cambisols are fertile soils, regosols are sometimes used for 'capital intensive' (high-input and high-financial gain) irrigated farming but are primarily used for low volume grazing	6

Polygon ID	Other Considerations	Rank
	and are amenable to terrace cultivation. Leptosols are shallow soils over hard bedrock or deeper very stony soil that have poor water retention and are undesirable for cultivation aside from some tree crops. Geology: Mixed, consisting of clay, marl, siltstone, chalk and deltaic gravels. Very minor tributary runs through but may be destroyed by power station. Slope is very low as polygon borders sea. Modern Landcover: Large power station with plans for a future power station slightly east. Most of the polygon is developed with c. 15% of the area under cultivation. No road accesses. Degree of Archaeological Knowledge: Lies entirely within the VVP but shows no pre-existing sites and may not have been surveyed as part of a transect either due to accessibility issues or it simply was not selected by transect placement.	
9	Soil/Cultivation: Largely comprised of regosols are sometimes used for 'capital intensive' (high-input and high-financial gain) irrigated farming but are primarily used for low volume grazing and are amenable to terrace cultivation and leptosols are shallow soils over hard bedrock or deeper very stony soil that have poor water retention and are undesirable for cultivation aside from some tree crops. Cambisols are present along the central portion of the long axis of the polygon, and these are fertile. Calcisols are soils with considerable lime presence and are of limited fertility unless irrigated, drained (to prevent salinization) and fertilised. Geology: Mixed combination of chalk and marl. Two tributaries run through the polygon. Modern Landcover: A popular beach and amenities reside within the polygon and comprise c. 40% of the polygon. Forest and a small area of cultivation comprise the remainder. Road access in central portion of the polygon. Degree of Archaeological Knowledge: Within VVP, but no sites previously identified. May not have been surveyed.	5

Table 7: Additional criteria that influence the ranking of polygons of archaeological significance for ground truth survey. These criteria include the soil type and its implications for cultivation practices, the geology which includes the bedrock formation, slope and presence of rivers, modern landcover which has implications for access and ease of survey and finally the prior archaeological knowledge including known sites and recommendations for actions by scholars or locals.

Step 7: Ground Survey Results.

Polygon 2 is selected for final ground survey for several stand-out reasons including

- its mixture of fertile and potentially fertile soils (provided terracing is implemented);
- its positioning along a river valley present throughout the prehistory of Cyprus;
- its low level of built-up area, presence of good road access and situation along the Ayios Minas riverbank and foothills (rather than the steeper slopes);
- it occupies an unexplored area of the study region, the ground survey of which would facilitate comparison of the lowlands and midlands of both Vasilikos and Ayios Minas valleys;
- survey is manageable over 5-10 days by two surveyors;
- and that it has been identified as having archaeological potential both prior to modeling (Todd 2013) and because of WoE predictive modeling.

A pilot ground-survey project was undertaken in the spring of 2017 albeit with limited financial, time and human resources. Ground survey (Figure 29) began at a road access point c. 2km north of Choirokoitia and proceeded northwest along the valley reaching the area of “favourable” sensitivity outlined in the final response raster for the late BA (Figure 27). Within the first day of survey, it became clear that the area was archaeologically rich and that a more intensive survey was prudent. Time permitted only an intuitive survey rather than comprehensive or transect based approach meaning that the path walked was based on the surveyor’s perception of both archaeological potential and ease of movement that favoured plateaus. It is hoped that a return will provide the opportunity to explore this area as well as AoI’s including polygon 6 and the western portion of polygon 1 more thoroughly.

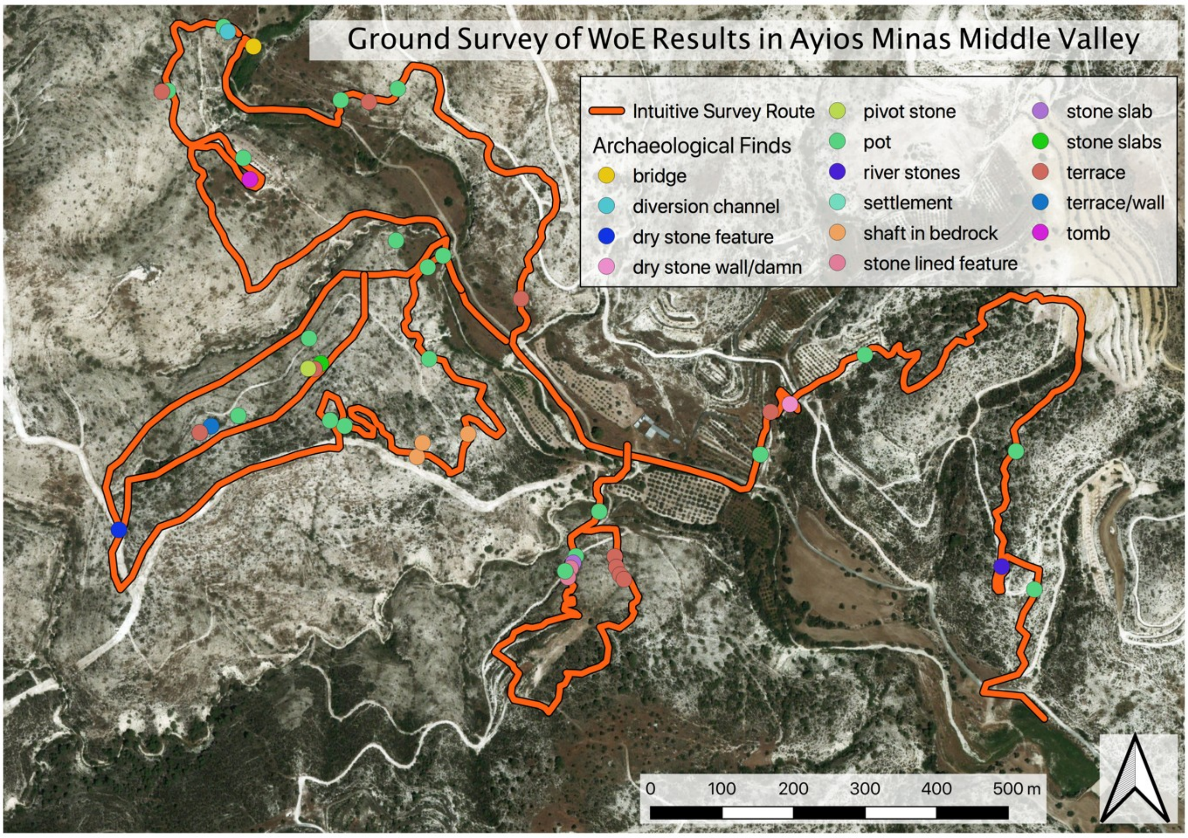


Figure 29: Detailed view of the ground-truth campaign undertaken in the Ayios Minas Middle valley, identified in Figure 22 as polygon 2. This figure shows the routes walked and the various finds observed. The routes were undertaken intuitively by following major breaks in relief with an emphasis on plateaus and areas surrounding known archaeological features. Base map from Google Earth, https://earth.google.com/web/

While a detailed analysis of finds has not yet been undertaken, some comments on the results of the walkover survey can be made. The materials observed seem to date from as early as the middle BA through to the early modern era (mid 18th century). Many features are likely medieval and post-medieval farming installations to manage water, domestic animals and to facilitate transportation across challenging parts of the landscape (i.e., rivers); however, one area does seem to strongly suggest a BA cemetery based on analogue tomb morphology and associated finds. This latter observation is of utmost interest to this study and is a priority for revisit.

7 Discussion

This study uses the weights of evidence (WoE) method for predictive modelling to identify areas of archaeological potential (AoAP) within the midlands and lowlands of the Vasilikos and Ayios Minas valleys. These models are constructed using a dataset of known sites and existing research into the spatial relationship between site location and landscape features. Three models were developed to predict AoAP for both coarse and finer chronological contexts. Model 1 looks for AoAP across all time periods with results amenable to more generalised diachronic studies (i.e., regional survey) and informing developers of potentially archaeologically sensitive areas. Models 2 and 3 focus on the early BA/earlier middle BA and later middle/late BA respectively and are used to predict diachronic settlement patterning and better understand the socioeconomic context within which it developed.

7.1 Model 1: Generalised Diachronic Model

Predictive models are now widely applied in both commercial and academic archaeology in many parts of the world (Kohler 1988; Dall Bona 1994; Verhagen et al. 2000; van Leusen 2002; Wheatley and Gillings 2002; van Leusen and Kammermans 2005; Verhagen et al. 2005). The power of these tools was immediately recognizable as they provide a decision support system useful for defining, organising, and prioritising ground-based survey and excavation (Danese et al. 2013) and can help address "a need for the identification, protection and management of increasingly threatened cultural resources in a cost-effective and useful manner" (Duncan and Beckman 2000: 33) in a non-destructive way. The designation of AoAP by means of predictive modelling help politicians and developers select land with the lowest 'archaeological risk' for their proposals (Verhagen 2007: 13) or at least provide justification for archaeological evaluation ahead of development in cases where location does indicate archaeological potential.

The map resulting from model 1 indicate areas that should be avoided by developers and investigated by academic and commercial archaeologists (Figure 30). AoAP identified in model 1 comprise 51km^2 with 7.5km^2 in the previously unexplored Ayios Minas valley and 43.5km^2 within the partially surveyed Vasilikos valley. These AoAP occupy land with ≤18 degrees of slope, covered with built-up or degraded land, planted with citrus or vegetables, on cambisolic, regosolic, gypsisolic, leptosolic and calcisolic soils and residing on the alluvium-colluvium, Apalos-Athalassa-Kakkaristra, Kalavassos, Pera Pedi and lower pillow lava geological formations. This combination of features can be found in other river valleys of Cyprus and may a wider indicator of archaeological potential.

Many of the AoAP identified contain known archaeological sites and in many cases these are distributed in such a way that few areas surveyed are likely to contain new sites but instead probably will yield extensions of material associated with these known sites. However, roughly half of the AoAP contain no known sites (for example, much of polygon 1 and all of areas 2, 5, 6, 8 and 9) and may indicate completely new settlements, cemeteries, or other types of sites. Encouragingly, these areas have been considered archaeologically significant by academics prior to conducting predictive modelling including the western half of polygon 1, 8 and 9 (Todd 2013) and polygon 2 in the north of the Ayios Minas midlands (Keswani 1996; 2004). In addition to these recommendations, further support that the predictive model was successful comes by way of the rich archaeological landscape identified by the ground truth campaign undertaken in polygon 2. There are several observations made during this ground campaign that can generate informative and robust field projects including excavation of a probable BA cemetery, survey of a long-lived terrace system and a higher resolution and standardised ground survey based on transect or grid segmentation.

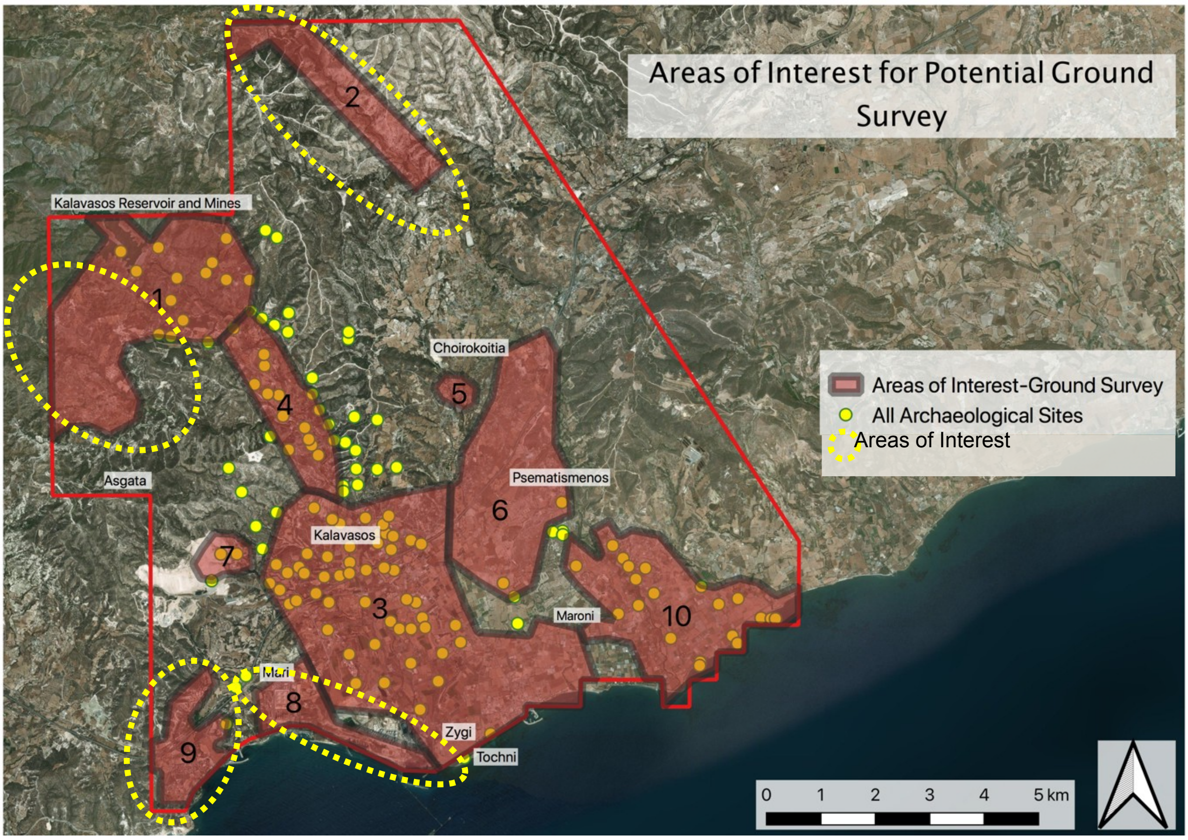


Figure 30: AoAP are indicated in red and given a number. Four areas resulting from the general predictive model for archaeological potential across all chronological periods are also suggested as promising by archaeologists in the past. These include a portion of polygon 1 as well as polygons 2, 8 and 9. Ground truth survey undertaken in polygon 2 in the unsurveyed Ayios Minas midlands proved archaeologically rich, the results of which could support several archaeological studies in several important areas including BA cemeteries and diachronic terracing in the midlands among others. Base map from Google Earth, https://earth.google.com/web/

7.2 Models 2 & 3: Settlement Patterning and Socioeconomics in Bronze Age Cyprus

The AoAP produced by models 2 (early/earlier middle BA) and 3 (later middle/late BA) are based on evidential themes selected for their influence on settlement patterning in the BA (underlying geology and the soils covering them) and a catalogue of known BA sites recorded during the VVP and MVASP surveys and other projects. The BA was selected because prior research, recorded sites and explanatory models explaining settlement patterning are heavily bias toward that chronological period (Knapp 2013: Keswani 1993, 1996; Manning 1993; 2002). Recorded sites and AoAP will be discussed within a three-part framework.

- within theory and explanatory models concerning the link between socioeconomics and settlement patterning outlined in section 3.

- within a four-region spatial framework derived from the geographical aspect of Knapp's (2013) four-tier "general" model:
  - Area 1: Cupriferous mixed geology (Upper Midlands);
  - Area 2: Fertile River Valleys Cutting the Less Fertile Chalk Plateau (Midlands Proper);
  - Area 3: Midland-Lowland Interstice (Midland-Lowland Boundary);
  - Area 4: Mixed Geology Lowlands (Lowlands Proper).

- within a two-period chronological framework of the early/earlier middle BA and the later middle/late BA.

This discussion will briefly revisit the hypothesised socioeconomic and political context of the early/middle and late BA that was detailed in section 3 followed by a detailed description of recorded settlements and AoAP and how they may be understood within this context. This discussion will be followed by a recommendation of AoAP for future investigation in-line with the research aims outlined in the introduction of the study.

7.2.1: Socioeconomics and Settlement Patterning in the Early BA and Earlier Mid BA
The early and middle BA was a significant departure from the preceding Chalcolithic period (Knapp 2013; Swiny 1989) due to an influx of foreign traditions and material culture influencing most aspects of life from food production and consumption to burial practices and property rights. During this time, settlement expanded in number and size as populations grew and occupied more agriculturally productive and mineral-rich land, particularly along the rivers and existing well-travelled routes (Knapp 2013: 297; Todd 2013). While more land was cultivated by more people, inhabitants continued to focus on the more easily workable but less fertile soils because the requisite draught animals and deep plough required to work heavy clay-rich fertile soils were rare and expensive. Moreover, the vast majority of people were concerned with domestic-level of subsistence supplemented by pastoral grazing rather than the high input and high yields that the fertile soils further south could provide. In short, the needs of relatively autonomous settlements of extended families and their households that owned their land and its yields (Frankel and Webb 2006a: 314-315) remained well within the carrying capacity of the less fertile soils. There exists very little evidence at this time of households cultivating surplus to feed in to an urban centre market system. Supporting this hypothesis are the modestly sized storage vessels and household sizes and lack of indicators for a site hierarchy at the time (Knapp 2013: 345). Moreover, burial practices at this stage consist of communal extra-settlement cemeteries that do contain a competitive element but overall retain modest differences in mixed local/foreign materials amongst individuals.

As the middle BA progressed, pressure from the rise in demand for prestige items such as copper both within and between settlements and for subsistence surplus to support those who worked to mine, refine and develop it in to goods, rose. The push to intensify production, unparalleled opportunities for greater wealth and therefore power and authority and the influence of foreign ways of living and thinking about socioeconomic relations encouraged greater competition among valley inhabitants. The degree to which competition undercut the mechanisms of socioeconomic co-operation is uncertain, however the emerging disparity between households, amongst burials and even settlements points to rising centralisation of wealth, power, and authority in fewer hands. Perhaps it was in burial that this change is best exemplified. Burials continue to occur outside settlements but become far more elaborate and expansive with a greater emphasis on acquiring foreign prestige items to indicate certain social groups, establish land rights and perhaps access to resources such as copper (Knapp 2013: 346).

Later Middle and Late Bronze Age
The later middle BA Cyprus saw a homogenisation of settlements structure, buildings, mortuary, and material objects which suggests an increase in inter-settlement contact society in which people shared beliefs, sought social alliances, and more widely integrated their socioeconomic activities (Knapp 2013: 351). In short, regionalism was breaking down. There is clear evidence in some areas of Cyprus for well-developed social stratification, central control of resources, industrial levels of copper and subsistence production and significantly enhanced trade and exchange networks that in some cases were conducted

under the authority of powerful elite groups in correspondence with foreign leaders (Knapp 2013: 353-54). This competition for prestige, power and authority manifested itself in many areas of the material record. Burials are now largely intra-settlement and show marked differences in material wealth with items sourced from throughout the eastern Mediterranean and beyond (Manning 1998b; South 2000) and a preoccupation with establishing ownership of land and resources such as copper. There is also marked intensification of ceramic vessel production, charcoal, stone and other resources from throughout the study area and beyond to the extent that settlements are established (and perhaps abandoned) based on their proximity and ability to access these resources, specialise in their production, and export their finished forms into these wider markets.

These material correlates are identified throughout the study area, yet it remains uncertain as to how well-developed settlement hierarchy was during the later part of the middle BA. Some have argued that Cyprus was organised according to a devolved authority amongst kin-based households (Peltenburg 1996) while others see it coming from a singular institution centred on the eastern coast in the site of Enkomi (Knapp 2013). Archaeological surveys and excavation in the study area including the VVP (Todd 2006c; 2013) and MVASP (Manning et al. 1994a) seem to show evidence for a tendency toward increasing regional centralisation with less evidence for island-wide control. It is perhaps reasonable then to suggest that organisation lay somewhere between these extremes.

By the end of the late BA many settlements were abandoned and in parts of the island, physically destroyed, with the inhabitants presumably dispersing into fragmented hamlets and villages. In the ensuing Iron Age, new “kingdoms” emerged from this fragmentation. Interestingly, including the study area, there is little to no evidence of destruction nor continuity but rather an ambiguous period of possible dispersal. The degree to which disruption occurred in the study area remains an open question with some labelling an absence of change as indicative of a relative backwater (Knapp 2013: 475). Recorded sites and AoAP may help identify where settlement was truncated, disrupted or endured into the Iron Age. Whatever the case may be, it seems increasingly unlikely that settlement across the entire island was completely disrupted at the end of the late BA.

7.3 Explanatory Models: Theorising Late BA Socioeconomics and Settlement Patterning

Keswani (1993) proposed a hierarchical regional model based on copper exploitation and trade. However, it is the opinion of the author that the most well-developed and appropriate model to frame discussion is Knapp’s (2013) hierarchical four-tiered ‘social model’ that is meant to be applied in general to Cyprus and does not necessarily claim that the study area was centrally controlled to the extent that others in the island were.

To recount, Keswani (1993) proposed that regions (synonymous with valleys) organised according to one of two settlement patterning models. These models are distinguished by the distance between what she terms ‘primary’ coastal centres engaged in copper export and the sources of raw copper (Keswani 1993: 79). If the distance was great, then primary centres had to rely on ‘secondary’ and perhaps even ‘intermediary’ settlements for the acquisition, processing, and transport of copper. “Primary” sites would fund this using portable and high value “wealth” finance such as finished copper items that would confer status on aspiring high status members, groups, families, etc. in the support villages. Keswani (1993) applied this model to the Vasilikos valley. If the distance was relatively small, primary centres could directly undertake extraction and beneficiation, but having exhausted their labour force in doing so, were reliant on acquiring food and other necessities from satellite agricultural settlements. In exchange for these subsistence goods they would supply these support villages with “staple” wealth in the form of expensive processed foodstuffs such as olive oil. In this case, primary centres would acquire olives from these settlements and process oil using expensive and rare industrial-level equipment. Keswani’s

(1993) models' were instrumental in demonstrating the complexity of intra-regional socioeconomic relationships, albeit from a top-down perspective of 'primary' centres.

Knapp's (2013) "social" model expanded upon Keswani's (1993) "regional" model by integrating environmental, agricultural, metallurgical, and politico-economic elements that provided a flexibility that the either/or "regional" model did not. Knapp (2013) postulated a "primary tier" of coastal centres conducting commercial, ceremonial, administrative and production functions; a "secondary tier" of inland towns managing administrative, production, transport and some storage functions; a "tertiary tier" of smaller inland sites serving ceremonial, production, transport, and some storage functions; and a "periphery tier" of agricultural and ceramic producing villages, mining sites among others serving production, storage and transport functions. In this study Kalavassos-*Ayios Dhimitrios* in the Vasilikos valley is considered a primary centre. However, it is unclear if the Maroni complex resides independently of a Vasilikos settlement system or within its late BA sphere of influence.

A sites "tier" is determined by the material correlates of resources if focused on (i.e. mining tools, pottery production accoutrements, olive oil processing, etc.), its geological position in the landscape and its size. Using this information, the AoAP can serve as proxies for sites and can be provisionally placed within the tiers of the "social model" and by extension hint at the structure of valley settlement both in the entirely surveyed Vasilikos and the partially surveyed Ayios Minas valleys.

Keswani (1993) and Knapp (2013) advocate for a hierarchical relationship between "primary" and "secondary" as well as "tertiary" and "peripheral" settlements with a clear power imbalance favouring primary centres. While an abstraction to be applied across the entire island, Knapp's (2013) model offers more explanatory power and affords greater inclusivity of the diversity of socioeconomic strategies and site types found in the study area than Keswani's (1993). For this reason, it will serve to contextualise the late BA recorded sites and AoAP outlined below. The following discussion will bring together the recorded sites and predicted AoAP for the purposes of addressing four questions:

i. In which AoAP might unidentified early BA sites be located?

ii. Are any of the AoAP proposed to contain early/middle BA sites good candidates for ground survey?

iii. Do AoAP proposed to contain late BA sites indicate a spatial structure to settlement? If so, does it suggest increasing hierarchy or continued relative decentralisation?

iv. Do any late BA AoAP indicate "bridge" or "link" settlements that connect the two valleys, particularly the large "primary" centers of the lowlands?

v. Do any early/mid BA AoAP hint at hierarchical development among settlements or this firmly to be placed in the later mid and late BA?

7.4 Analysis of Recorded Sites and Areas of Archaeological Potential by Area

The following analysis considers recorded sites of the VVP and MVASP surveys and predicted AoAP from the early/mid BA and the late BA. AoAP that contain no (or few) previously identified sites, areas noted by academics and locals as worthy of future investigation and are mentioned by theory and model conclusions based on recorded evidence will be recommended for investigation are of particular emphasis. Material remains belonging to the known sites collected both during survey and excavation are central to building context for AoAP, particularly longterm changes to settlement patterning, socioeconomics, and settlement hierarchy at a regional perspective. This analysis will be framed according to the four main geographical zones 1) Cupriferous mixed geology of the upper midlands; 2) The Fertile River and Lefkara Chalk Plateau of the Midlands Proper; 3) the Midlands-Lowlands Interstice; and 4) Mixed Geology-Marls and Fertile Alluvial Soils (Figure 31).

The main themes of change discussed include:

- proximity to soils (as evidence for cultivation intensity, technology)
- proximity to copper and other resources (as evidence for specialisation in labour-intensive/high-value economic production)
- number and size settlements (as evidence for urbanism and socioeconomic complexity including centralising tendencies)
- inter-settlement v. intra-settlement burial (as evidence for economic competition and emphasis on private property and land rights)

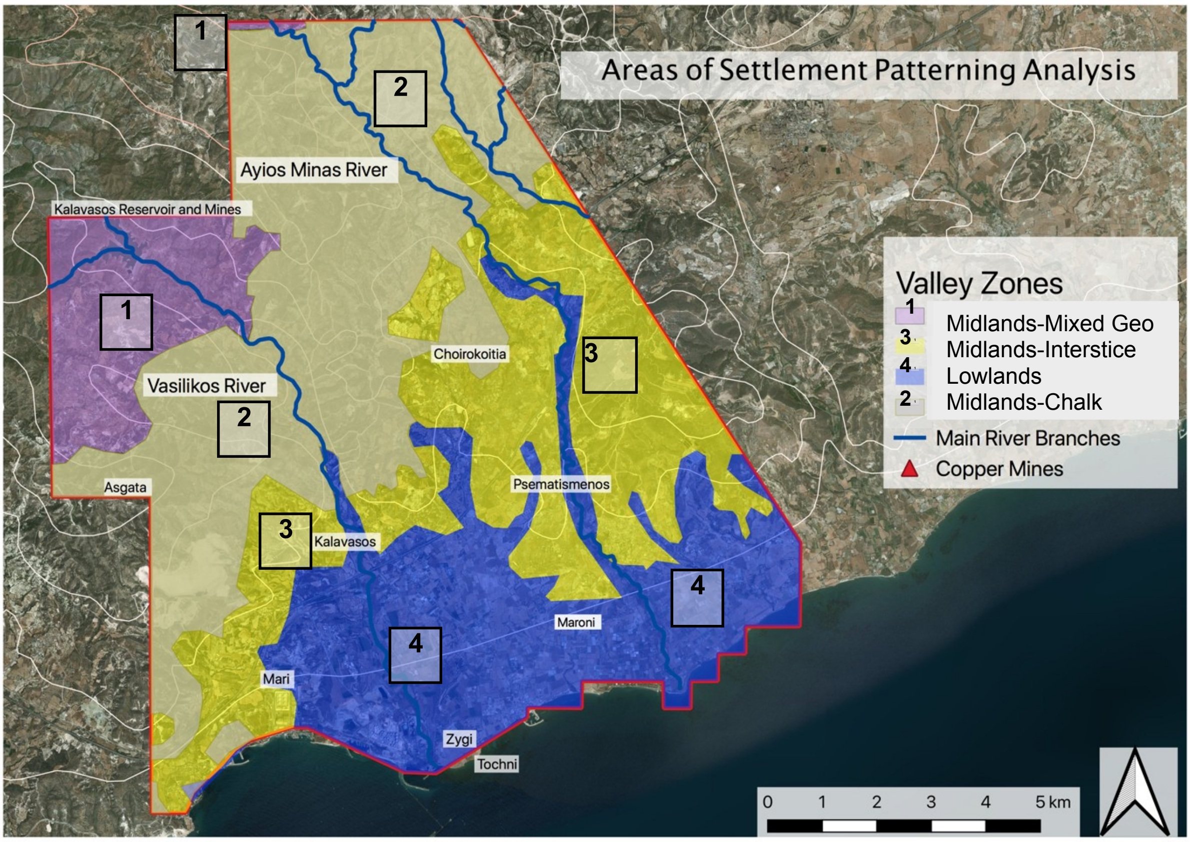


Figure 31: This map depicts the four areas (per valley) that will be used to frame discussion on diachronic settlement patterning and socioeconomic evolution in the Vasilikos and Ayios Minas River valleys during the Bronze Age. These include Area 1: Midland Mixed Geology (purple); Area 2: Midland Chalk Plateau cut my Fertile River soils (Beige); Area 3: Midland/Lowland Interstice (Yellow) and Area 4: Lowlands Proper (Blue). There is no clear boundary between the two valleys and as will be seen, settlement permeated this middle region over time to the extent that they probably should not be considered separate entities. Also note that the various areas are not identical in areal extent (nor are they uniform in their soil distribution) due to a combination of geology and study area boundary selection. For example, area 1 is significantly larger in the western Vasilikos valley than in the Ayios Minas valley due to the southeast to northwest trajectory of the chalk plateau and the placement of the study area boundary that truncates area 1 in the Ayios Minas valley. Another example is that area 3, which comprises a chalky-marl zone between the chalk plateau and fertile valley lowlands is significantly larger in the eastern Ayios Minas valley than in the western Vasilikos. Base map from Google Earth, https://earth.google.com/web/

7.4.1 Area 1: The Cupriferous Mixed Geology of the Upper Midlands

Area 1 (Figure 31) comprises the cupriferous pillow lavas, gabbro and sheeted dykes overlain by regosolic, leptosolic and cambisolic soils of the upper midlands. The regosols and leptosols of the riverbanks are made productive through terracing or animal grazing while the pocket of fertile cambisols would have been less useful at this time until draught and deep plough technology became available. Area 1 is comprised of about 85% regosolic/leptosolic soils and 15% cambisolic soils with the latter confined to the southwest. It would be reasonable then to suspect that settlement would expand to the southwest over time to make use of these fertile soils once the requisite technology became available either to high status/opportunistic people early on or to the general populace later.

Area 1 was settled early on, probably due to its position on easily workable and sufficiently fertile soils and between the uplands that are rich in copper, timber (Kassianidou and Knapp 2005: 235), chert stone (Pearlman 1985, 46-47, 130, 135-136), wild game, valuable plants as well as gypsum (Todd 2013: 6) and the coastal lowlands that offered seafood, salt (Ikram 2000: 663-668; Laubier 2005: 16-20) and access to coastal routes of transport and exchange of goods and ideas. This suite of resources provided a solid base upon which to satisfy domestic-level subsistence and acquire specific resources to funnel into the expanding trade and exchange systems developing throughout the middle to late BA.

In the Vasilikos valley, area 1 is well represented both in areal extent and by recorded settlement count. By contrast, area 1 in the Ayios Minas valley is both physically underrepresented (as it is located much further north and outside the predictive survey boundary) and in recorded sites as no formal survey has been conducted in the area. These limitations make inter-valley comparison of area 1 difficult but fortunately enough was captured to prompt a productive ground-based survey.

Recorded Sites

Vasilikos Valley-Pre BA to Earlier Middle BA

The earliest recorded sites in area 1 of the Vasilikos valley were established in the middle to late Chalcolithic (2600-2400 Cal BC) and abandoned in the earlier middle BA (c. 1750 Cal BC). They include the settlement of Asgata-*Neron tou Phani* and the cemetery of Asgata-*Kambos* c.0.9km from the western riverbank near the border of area 2 (Figure 32, 37). Due to their spatial and chronological proximity it is probable that they were constructed by closely socioeconomically and possibly biologically related groups and therefore provide a good opportunity to consider the relationship between diachronic development (or existence) of wealth disparity and economic intensification.

Early Middle BA

There are several sites in the study area that were both established and abandoned within the middle BA over a period that may represent anywhere from a century to 500 years (c. 4-20 generations). These settlements occupy a very early time in the transition from domestic-oriented economic activities to more intensified ones. These settlements saw significant shift, abandonment, amalgamation, and overall size increase within a relatively short time. Examples include Ora-*Klitari* and Ora-*Loures* (Figure 32, 37). Some sites were able to remain in their founding location into the late BA such as Ora-*Ammouthia* located roughly 0.2km northeast of Ora-*Klitari*. This early transitional period can be understood as one of elasticity and perhaps experimentation in settlement location choice with some being more successful than others in anticipating the most advantageous positions to best access the embryonic primary centres, exploit in-demand resources such as copper, stone and perhaps cultivated goods and interact with coastal ports and merchants, etc.

Ayios Minas Valley-Early and Earlier Middle BA

No official survey work has been conducted in area 1 of the Ayios Minas valley. However, as a follow-up to the results of predictive modelling it was informally walked-over by the author.

Preliminary results point to a rich archaeological landscape with evidence for occupation spanning the Chalcolithic through into the early modern era. Noteworthy observations include a potential early/middle BA cemetery and other BA material hinting at early, middle, and late BA settlement (Andreou, personal communication). The BA material was observed in a sufficiently limited area to suggest it derived from a single settlement signifying sites that were as long-lived as in area 1 of the Vasilikos valley.

Areas of Archaeological Potential

Vasilikos Valley-Early and Middle BA

Eight AoAP were identified in area 1 for the early BA and earlier middle BA in the Vasilikos valley (Figure 34). The western six are more likely to produce new sites as they contain no previously recorded sites. The AoAP's also surround a pocket of rare (for the area) cambisolic soil, are near known copper sources and have been cited as needing further investigation by the director of the VVP (Todd 2013). These areas should be investigated as they have the potential to clarify long term strategies to copper, soil, and river exploitation. Further investigation of this areas could also elucidate settlement transition from domestic-level subsistence to more industrial scale exploitation. Tracking the shift of copper from curiosity to local prestige material to source of income from international trade could be investigated within these AoAP and provide insight into the history of copper exploitation.

Ayios Minas Valley-Early and Middle BA

Two AoAP were identified in area 1 of the early BA to earlier middle BA in the Ayios Minas valley. As the area has not been formally investigated both AoAP should be ground surveyed as they contain no known sites and uncertainty surrounds the nature (or even existence) of upper midland settlement and copper exploitation. Future research should include a more substantial survey between the area informally surveyed to the south by the author and area 1. This would effectively extend the range of known settlement in the unsurveyed portion of the Ayios Minas valley and lead to a better understand early strategies of soil and copper exploitation along the length of the valley in the first half of the BA.

Later Middle and Late Bronze Age

Recorded Sites

Vasilikos Valley-Late Middle BA

In the later middle BA (1750-1450 Cal. BC) in area 1 of the Vasilikos valley, nine sites (Figure 33) were established that remained occupied into the late BA (1450-1125 Cal. BC) with possible disruption into the ensuing Iron Age. Clustered east of the river, these sites include Asgata-*Ayia Marina*, Ora-*Betaleyi,* Ora-*Mazo Kambos,* Ora-*Aspro Khorapha,* Ora-*Lakxia Constandi,* Ora-*Mersina,* Kalavassos-*Markotis,* Kalavassos-*Mazeri* and Kalavassos-*Kharkokolymbos* and may represent as few as five settlements (Figure 33, 37). These new settlements indicate a northern and an eastern trend up along the river and toward the Ayios Minas valley respectively. This shift north situates occupants closer to the cupriferous deposits (and perhaps existing mines) located along the northern fringes of the study area and beyond to meet the increasing demand for copper that would be transported south and possibly east. The purpose of the eastern shift is less clear but may indicate effort to improve inter-valley communication, exchange, and economic co-operation. Shifts in other areas of the study area mirror these efforts and support current theory (Knapp 2013; Keswani 1993) that settlement expanded to facilitate the coalescence of the valley(s) into an integrated and hierarchical economic system focused on copper and other high value items for exchange in prestige markets throughout the island and abroad.

Ayios Minas-Late BA

No formal archaeological works and therefore no recorded sites are present for the Ayios Minas midlands in the late BA; however, preliminary survey undertaken by the author did identify late BA pottery associated with earlier material suggesting it belongs to a settlement with early BA roots demonstrating long established settlements adjacent cupriferous geological deposits and reasonably fertile soils.

Predicted Areas of Archaeological Potential and their Socioeconomic Implications

Vasilikos Valley

By the later middle to late BA, AoAP in area 1 of the Vasilikos valley show a combination of settlement consolidation and relocation (Figure 35). Settlement is predicted to relocate from the southwestern AoAP and consolidate on/near the fertile cambisol pocket further south. Settlement is also predicted to have relocated/shifted north along the river toward cupriferous deposits; east toward the Ayios Minas valley as indicated by the recorded sites but also south toward area 2; closer to fertile soils that would enable higher yield cultivation; and toward the burgeoning Kalavassos cluster of sites that would have provided a large market for subsistence surplus due its preoccupation with intensified copper and olive oil production.

Priority should be placed on the portions of the southwestern AoAP that overlap the marginal soils surrounding the fertile pocket as this area lacks known sites and, as will be seen, late BA farmers settled the marginal fringes of fertile pockets of soil so as not to waste valuable soil by building upon it. If earlier sites exist in this area, it provides an opportunity to study diachronic intensification of crop production as settlement is predicted in these areas in the early BA. This area may also contain copper mining villages and loci of beneficiation that could increase knowledge of metal working and trade in the valley. In the east, the two AoAP along the western side of the river should be investigated as they also lack known sites; may contain evidence for copper beneficiation; and may provide the opportunity to identify settlements that border the uplands of which none are known in the study area. Areas of overlap in AoAP between early/middle and the late BA should also be investigated as they amy provide insight into the ways in which settlement developed over time, particularly regarding resource focus, size/density and participation in prestige markets through increased accessed to foreign objects. Finally, the area between the easternmost sites and the area informally surveyed by the author in the Ayios Minas midlands should be considered as this area may contain settlements that bridge the two valleys.

Ayios Minas

The AoAP identified for late BA area 1 of the Ayios Minas valley comprises c. 40% of the total area. No formal survey has been conducted here and little is known of the archaeological record which positions it as a strong candidate for intensive ground survey. Intensive survey here would provide a good opportunity to gauge the nature and extent of late BA midland settlement in the Ayios Minas, determine whether copper was directly exploited by these settlements and clarify their relationship, if any, with their contemporaries both in the southern Ayios Minas midlands (areas found in informal survey), lowlands (i.e., the Maroni Complex) and in the Vasilikos valley (particularly those mining copper). However, should it prove archaeologically unproductive then reasons for why inter-valley development varied despite there being a "primary" centre in both would require answers perhaps related to the relationship between demographic pressure and resource abundance/scarcity. It would also call into question the purpose of the Maroni complex within the "social" model if there seemed to be no support sites.

If evidence of settlement north of the Maroni complex or more specifically copper exploitation is lacking or absent, then it may be that settlements in area 1 of the Ayios Minas were engaged in acquiring copper from the Vasilikos valley, were exploiting other resources, or simply focusing on domestic-level subsistence. However, if evidence for copper exploitation is present it would be useful to determine whether this was extractive (from a local source) or post-extractive (from a non-local source such as the Vasilikos valley). If extractive, it could be posited that both valleys had access to their "own" copper deposits and were on somewhat of an equal competitive footing. If post-extractive, this would have had important implications for socio-political relations between the settlements of the two valleys, particularly the primary centres. These enquiries into copper access tie into questions of whether the primary centres function independently or within a larger socioeconomic system.

Provisional Placement of Sites and AoAP in Knapp's Settlement Hierarchy
Recorded settlements and AoAP (as proxies for later middle and late BA settlements) can be provisionally placed within tiers of Knapp's (2013) 'social' model and provide context. Settlements in the area 1 would belong to the periphery and tertiary tiers likely be engaged in the production, storage and transport of subsistence, pottery, and copper (Figure 36). Recorded settlements show that several resources were exploited but copper as paramount. Material correlates of industrial production of copper would include unroasted and roasted copper ore, potentially copper slag (as smelting by-product) and other accoutrements of copper beneficiation. Evidence for industrial ceramic production would comprise large quantities of clay storage, by-products of firing known as "wasters" and large number of fired vessels. Evidence for industrial grain processing would involve large threshing floors, grinding implements and storage vessels. Finally, one might also consider evidence for olive cultivation. Determining whether these activities were industrial or domestic is difficult and requires some understanding of population density, when storage passes the domestic requirements threshold in to surplus and the degree and nature of inter-site connection along and between the valleys.

7.4.2 Area 2: The Fertile River and Lefkara Chalk Plateau of the Midlands Proper
Area 2 (Figure 31) comprises the chalk plateau bisected by the two rivers is the most extensive in the study area. Settlement was long-lived and dates to at least the Chalcolithic indicating a landscape that supported settlement for millennia despite changing economic necessities and technology. The geology is overlain by marginal and underwatered lithosolic soil containing pockets of regosols that can be made productive through irrigated terracing and pastoral grazing. Fertile cambisols are present along the lower half of area 2 in the Vasilikos valley and in a pocket midway down the area on the western side of the river. This relatively fertile corridor proved important in maintaining communication and exchange of goods and ideas, subsistence cultivation and potentially sources of clay. There are no such fertile soils in area 2 of the Ayios Minas valley. Despite the benefits of these fertile pockets in the Vasilikjos, their proximity to rivers that are prone to erosion, torrential flooding and evaporation in the summer months make settlement along their banks unreliable. This unreliability very likely contributed to some of the drift and resettlement observed over time.

As with all areas of the study region, area 2 differs in the distribution of its geological deposits and overlying soils in the two valleys. In addition to the absence of fertile cambisols in the Ayios Minas valley, the chalk plateau is ~30% larger. If settlement was sustained in the Ayios Minas valley, despite a lack of fertile soils, it may help identify the degree to which the fertile soils in area 2 of the Vasilikos supported contemporary settlement there. Informal ground survey in area 2 of the Ayios Minas does demonstrate that some degree of settlement was present in the Early/Mid BA, but further south the archaeological record is murky. Limited settlement may suggest that the presence of fertile soils is instrumental to widespread settlement in area 2 as is present in the Vasilikos valley. However, if settlement is present then it might be posited that an alternative approach to the subsistence economy of the Vasilikos valley was present.

Pre, Early BA and Earlier Middle Bronze Age
Recorded Sites
Vasilikos Valley-Pre and Early BA
The earliest sites in area 2 of the Vasilikos valley date between the Chalcolithic and Middle BA (Figure 32, 37) and comprise small domestic-oriented autonomous villages. These include the settlement of Kalavassos-*Melisotriba East* situated c. 0.5km south of the area 1 boundary, the cemetery of Kalavassos-*Yirtomylos* located c. 0.5km on the east side of the

river to the southwest, the settlement of Kalavassos-*Arkhangelos* c. 0.85km south and the settlement of Kalavassos-*Ipsopamboulos* c.2.2km southeast on the west side of the river near the border of area 3. Three of the four earliest sites were settled along the river in the north of the area, adjacent area 1, presumably to access the bountiful resources of the midlands/uplands rather than focusing on the heavier fertile soils that required rare and expensive technology south. The fourth site is in the far south on the east side of the river on the border of area 3. All sites were situated within 100m of the marginal soils better suited to the technology and subsistence capabilities of the time. These early settlements show a preference for the river (<1.0km distant) and interestingly fail to adhere to the western bank of the river that was suggested as a longstanding travel route by Todd (2013).

Earlier Middle BA

By the earlier middle BA settlement had expanded both north and south but remained relatively sparse. This patterning foreshadows later middle BA settlement in the southern part of the area and may represent early attempts to exploit more fertile soils, perhaps a few individuals, a lineage group or co-operative. This may have been marginal as the socioeconomic environment conducive to high surplus cultivation is not thought to have existed to an appreciable degree at this time. In the opposite direction, the shift north improved access to mining villages that acquired raw copper and processed it for transport south - another trend that was realised by the later middle BA in the south of area 1. It's possible that settlements being placed closer to specific resources were reorienting themselves toward specific tasks/roles in an increasingly export-focused economy. Nine settlements are founded and subsequently abandoned in the middle BA in area 2 of the Vasilikos valley suggesting a perhaps experimental and tenuous relationship with location.

In the north, four settlements, Kalavassos-*Spilios* and Kalavassos-*Ayios Kaloyeros* both west of the river and Kalavassos-*Melisotriba* and Kalavassos-*Yeromano* found between the southern border of area 1 and the fertile cambisols of the river comprise a c.1.0km^2 cluster (Figure 32, 37). These settlements are located within a few hundred metres of several earlier sites that may suggest slow settlement drift or a perhaps more rapid and conscious relocation due to the changeable and unstable relationship to the environment as well as a strategy to secure access to the cupriferous upper midlands. *Spilios,* a particularly large settlement for the period demonstrates the trend toward settlement growth that emerges in the first half of the BA. Further south, some of these settlements have been considered "megasites" by Knapp (2013: 351).

Three additional sites belong to a southern cluster. These include the tomb of Kalavassos-*Village Cinema Area* and the settlements of Kalavassos-*Angastromeni* and Kalavassos-*Potamia* found on the western side of the river i~1.0km from the border of area 3 and adjacent to fertile soils (Figure 32). These settlements are better situated to farming fertile soils and perhaps to liaise/co-operate with southern settlements, that would later be considered "primary" centres, of the upper lowlands and coastal plain. It is possible that these settlements are linked to the slightly later origins of the Kalavassos cluster surrounding the "primary" centre of Kalavassos-*Ayios Dhimitrios* c. 1.0km south.

Further south, apart from these two clusters, are found two sites. One, Kalavassos-*Bamboules* is located c.1.2km to the west of the southern cluster relatively far out into the marginal chalk plateau. The other settlement of Kalavassos-*Fournia* is located on the east side of the river at the boundary of area 3 bordering fertile river soils. While *Fournia's* position is comprehensible, being located close to fertile soils, the developing Kalavassos cluster and the lowlands, the marginal position of *Bamboules* is less clear and may indicate the presence of an unknown resource or perhaps a sanctuary function.

Throughout the BA, areas 2 and 3 would have increasingly become a nexus for the facilitation of trade, exchange, communication and transport between the coast, lowlands, midlands and uplands, intra-island regions and eventually the wider Mediterranean world system. The soil workable soils and position between the lowlands and uplands of areas 2 and 3 could sustain the household-level subsistence requirements of the early/middle BA but also facilitate early experimentation with a mixed landscape strategy. With an emphasis on household production early on, some individuals, groups and perhaps entire villages through advantage, fortune and skill were well placed to slowly developed the knowledge and proficiency to productively exploit the fertile lowland soils and produce subsistence surplus, lucrative cultivars such as olives and even copper. As the demand for such skills and products increased, they would have found themselves in an advantageous position as the later middle BA emerged. Others would have to relocate or merge with their better situated and more economically successful neighbours.

Ayios Minas Valley

No recorded sites are known in area 2 of the Ayios Minas valley due to the lack of formal investigation (Figure 32). However, informal survey in the southern portion of area 1 and northern portion of area 2 found evidence of long-term BA settlement from the early and Middle BA. Further excavation is necessary to improve understanding of their socioeconomic orientation.

Predicted Areas of Archaeological Potential and their Socioeconomic Implications

Vasilikos Valley

Area 2 in the Vasilikos valley contains a c.2.6km x c.0.3km AoAP along the central portion of the river (Figure 34). This corridor is skewed to the western side of the river, which aligns with the theory (that remains unsubstantiated by recorded sites predating the early BA) of an ancient travel route along the western Vasilikos riverbank that may predate the BA (Todd 2013). The AoAP supports the likelihood that reasonable proximity to the fertile river valley was essential for permanent settlement of the midlands proper from early on. The high density of sites within the AoAP may suggest that the AoAP reflects the presence of known sites rather than predicting new ones. The central and southern portions of the AoAP possess fewer sites and could be earmarked for intensive re-survey (as the VVP employed an extensive approach). However, relative to other areas, the AoAP is of moderate to low priority for further survey.

Reinvestigating these areas may help clarify the relationships between sites of close proximity and determine whether they may be related by circumstantial settlement drift or a more deliberate and discrete relocation strategy. Investigation into these zones may also clarify the nature of the settlement shift observed throughout the valley in the earlier to later middle BA. Two areas of primary interest would be the role of these smaller villages in provisioning large urban centres with subsistence goods and what they received in exchanged and secondly, how the intensification of copper exploitation changed inter-settlement relationships.

Ayios Minas Valley

There are no AoAP identified for the early BA/earlier middle BA in area 2 of the Ayios Minas valley. This is due in some part to there being no recorded sites upon which to base predictions but probably more to the scarcity of workable soils that seem to attract settlement in contemporary Vasilikos valley. Despite projections, we know from the recorded sites in the Vasilikos valley that some degree of settlement existed in marginal landscapes and preliminary informal survey has shown the BA was here. How (or whether) such settlements fit in to the socioeconomic model of the late BA and what they were producing is poorly understood. Future investigation should continue to move south in an extensive ground survey to gain a better general understanding of whether the same processes of settlement reorientation were underway in the Ayios Minas valley as were occurring in the Vasilikos.

Later Middle to Late Bronze Age

Recorded Sites

Later Middle BA

Vasilikos Valley

In the later middle BA, a significant re-orientation and densification of settlement within the lower 2/3rds of area 2 is observed which saw settlement extending along the entire length of the river rather than clustered (Figure 33, 37). Many of these later middle BA settlements occupy new locations on marginal land adjacent fertile soils as a strategy to maximise cultivation of fertile soil by not building on it. This indicates a trend of the middle BA, namely the intensification of cultivation to support villages specialising in production of non-subsistence goods such a copper. Not all settlements of this period inhabit previously unsettled land as some earlier settlements do endure with only small degrees of drift through small choices to re-situate buildings, fields, animal pens and refuse heaps over tens of generations.

Sixteen settlements within four general locations are established in area 2 of the Vasilikos valley in the later Middle BA (Figure 33, 37).

1) Three sites along a ~1.0km north-south oriented line within 0.25km of the western riverbank adjacent to and within the fertile pocket of cambisols (Kalavassos-*Gouppos*, Kalavassos-*Kondon Klisourin*, Kalavassos-*Laroumena-cemetery*). The location of these settlements provides access to fertile soil, occupies the midway point between the coast and cupriferous deposits of the upper midlands and facilitates the control/administration of north to south transport, communication, and interaction of these areas. *Laroumena* shows evidence for supporting some of the larger sites through its production of food surplus, copper, and textiles.

2) Three sites to the east along a ~1.2km long southwest to northeast oriented line extending from the river out toward the Ayios Minas valley (Kalavassos-*Pervolia*, Tochni-*Oriti North* and Tochni-*Oriti South)*. *Pervolia* is close to the fertile river and may seemingly have more in common with the group above, the twin *Oriti* sites (which are likely a single settlement) are intriguing for their longevity in what appears to be a marginal zone suggesting that proximity to fresh water and fertile soil wasn't essential to long term occupation. It has been suggested that despite their intervening distance *Perivolia* is a continuation of the *Oriti* cluster*. It* may be that the site served (and benefitted) from acting as an intermediary between valley settlements, perhaps for the provision of copper for subsistence and other goods if settlements in the Ayios Minas did not have access to their own metal sources. These sites show evidence for a wide variety of goods production/possession including subsistence surplus storage and copper smelting.

3) Seven sites within a 0.7km^2 cluster in the lower third of area 2 and largely on the eastern side of the river (Kalavassos-*Village/Panayia Church Area,* Kalavassos-*Village Church/Mavrovouni,* Kalavassos-*Kaparovouno*, Kalavassos-*Ammos*, Kalavassos-*Argaki tou Tahiri*, Kalavassos-*Ayiasmata* and Tochni-*Kapsala)*. This cluster occupies marginal soils within ~1.0km of three sources of fertile soil (west on the river and southeast in area 3). Its location on the eastern side of the river and longevity of occupation (into the late BA) suggests that both banks of the Vasilikos are by this time well travelled. This cluster was almost certainly situated to benefit from the pockets of marginal soils amongst large areas of high-input/high-yield cultivation enabled by the massive quantities of fertile soil. As with their neighbors to the north and west, the villages were probably supplying subsistence support to the primary Kalavassos cluster in the lowlands in exchange for olive oil and other subsistence wealth.

4) Three sites along a 1.0km line of settlement adjacent to the border of the midland/lowland interstice (area 3) (Kalavassos-*Kokkino Kremmos*, Kalavassos-*Lourca* and Tochni-*Latomaes)*. These sites demonstrate the trend toward movement south in the later middle and late BA to limit distance from the Kalavassos cluster in the midland/lowland interstice (area 3) that became the primary center of Kalavassos-*Ayios Dhimitrios.* While almost certainly involved in intensive subsistence cultivation of the fertile soils immediately south, the settlements were also well placed to administer the flow of goods along the valley. The density of sites in this area is high and it is possible the Kalavassos cluster may have extended this far east. A final site Kalavassos-*Zoulfdidhes* is located 2.4km west at the edge of the southern Kalavassos cluster, probably making it the western extend of the Kalavassos cluster.

The significant increase in the size and number of settlements, the abandonment/relocation of the earlier middle BA villages and the shift south in the later middle BA (i.e., *Kokkino-kremmos* and *Lourca)* suggests a state of flux instigated by the demand for subsistence surplus to support the primary centre and surrounding cluster of villages focused on copper and high-input/high-yield cultivation of the fertile soils in the central lowlands. This surplus production would be exchanged for staple wealth such as olive oil and other prestige items (i.e., finished copper goods) that populate the burials of the late BA. It is also particularly interesting that 13 of the 16 settlements containing a late BA component possess what appears to be a gap or hiatus in settlement until the later Iron Age. It is uncertain what this gap represents, though dispersal rather than destruction is more likely.

Late BA

Vasilikos Valley

Despite being a period of considerable social, economic, and political activity, most settlements involved were established in the later middle BA (Figure 32). In the Vasilikos valley only Kalavassos *Village-Plot 37* located midway down the area on the river originates in the late BA and even then, its proximity to its predecessors (<200m) suggests it may be a product of settlement drift or perhaps the consolidation of the surrounding settlements (Figure 34). The location, midway along the river between area 1 and 3 amid fertile soils and several other late BA settlements, could support the hypothesis of consolidation in response to the developing administrative needs of a tiered settlement system reliant on the transport of goods along the valley. As with area 1, most late BA sites contain an Iron Age component, though a gap in settlement is present that could be linked to the disruption in exchange routes within the eastern Mediterranean at the time.

Ayios Minas Valley

No recorded sites are known in area 2 of the Ayios Minas valley due to the lack of formal investigation (Figure 32). As with the earlier periods in this area, there is evidence for late BA settlement in the northern portion where informal survey was conducted suggesting a lengthy occupation spanning the entire BA.

Predicted Areas of Archaeological Potential and their Socioeconomic Implications

Vasilikos Valley

AoAP for later middle and late BA area 2 show an increase in overall settlement density, though much of this was largely established by the end of the middle BA (Figure 35). Later areas of notable expansion include the western side of the river corridor and the north and south portion of the area such that it by the late BA settlement connects with AoAP in neighbouring areas (Figure 35). The AoAP reflect the trend for settlement built on marginal soils to maximise cultivation of the fertile varieties. If this is the case, any such settlements found in the AoAP should show an increase in subsistence storage technology including storage vessels and larger grain processing tools such as ground-stone grinders than those found in individual households. *Laroumena* is a good example of a known site in the area linked to intensive food surplus production. The less fertile areas where people settled also happen to better facilitate the movement of other goods along the valley including copper, timber, textile, and ceramics among others to and from the “primary centre” and support settlements.

Two areas of the AoAP that lack known sites would benefit from ground survey. The western north portion within the uppermost oxbow in the river and the southwestern portion just northeast of the Kalavassos cluster. In general, further survey along the west of the river could clarify whether there are grounds for a “western route” as claimed by Todd (2013). Independently, survey of the northern portion may help identify further villages dedicated to the acquisition and movement of copper with concomitant received goods from the primary centres and perhaps lowland ports. Any sites in the southern portion may help link settlements in areas 2 and 3 as presently the area remains a void for settlement between the Kalavassos cluster and the river-bound settlement of the midlands. Survey intended to build the record of burials would also help demonstrate to what degree a prestige economy was based on foreign v. local goods and from where said goods were acquired.

Ayios Minas Valley
There are no AoAP identified for the later middle and late BA in area 2 of the Ayios Minas valley. As with the earlier model, this region has no recorded sites upon which to base predictions nor does it share the geological complexity of the Vasilikos valley making it an unlikely candidate to contain settlements based on the training and evidential themes of the models. In particular, it is the presence of tendrils of fertile soil that wind north along the Vasilikos river and the pocket of fertile soils on its central western bank that have no counterpart in the Ayios Minas that seems to prevent AoAP in the latter. However, this does not mean that settlements did not exist, in fact informal survey revealed that at least in the northern extremity of area 2 there was late BA settlement. What can be said is that this settlement was either not predicated on the same geological recipe as in the Vasilikos valley ro that fertile soils slightly further away supported it. Perhaps settlement at this northern extent was possible due to fertile soils found in area 1 of the Ayios Minas. Future investigation should move both south into the chalk plateau, but also north outwith the study area to locate any fertile soils and identify potential settlements associated with their cultivation. Survey should also take care to record evidence for alternative or supplementary resources that might have been exploited alongside or in lieu of copper.

Of key interest in this study is understanding the way in which the valleys interacted. Were they co-operating in a heterarchical system of mutual benefit or a hierarchical tiered system that extended throughout the entire study area and perhaps beyond? How far back can interaction be observed and was this a continual intensification of contact over the BA or did it ebb and flow? Settlements that were exchanging with those in the Vasilikos remain elusive. Investigation in and around the liminal zone, including the *Oriti* cluster would be beneficial as the sites suggest an array of goods were passing between the valleys.

Provisional Placement of Sites and AoAP in Knapp’s Settlement Hierarchy
Within Knapp’s (2013) social model, settlements along the fertile corridor of area 2 could be categorised as “tertiary” and/or “secondary” with a responsibility for the acquisition, processing, administration and transport of subsistence surplus, copper and other resources and in some cases possibly serving as rural sanctuaries for the region where administrative and ritual activities combined to coordinate the socioeconomic system (Figure 36). Settlements outside of the fertile band may be better conceived of as occupying the “tertiary” group (Knapp 2013) dedicated to resources outside of copper and crops such as ceramic production.

Material evidence required to support these claims would include evidence of later stage copper production in northern villages such as slag from the smelting process as well as fluxes such as limestone used to remove impurities. Villages specialising in crop surplus production could be identified by large storage vessels and industrial grain processing tools. Evidence for administrative control and organisation of goods exchange/transport could include storage vessels, seals and perhaps unique objects obtained from coastal contacts and intra-island exchange partners. Some settlements that exist beyond the typical 300-500m from the river could be specialising in resources outside of crops and copper such as ceramics, operating as sanctuaries which would possess their own unique material correlates or even serving as intermediaries between the two valleys, though such interaction would be more easily facilitated in the more populous and fertile coastal lowlands within ports and perhaps market sites.

7.4.3 Area 3: Midlands-Lowlands Interstice

Area 3 comprises the midland/lowland interstice (Figure 31). Geologically, this region is an intervening zone as it resides between the relatively homogeneous chalk plateau of the midlands proper (area 2) and the mixed, but generally fertile geology of the lowlands (area 4). Predictably, the area comprises a mixture of chalky-marl (akin to area 2) and fertile alluvial/colluvial cambisols (area 1). Area 3 is crescent shaped and oriented with its “mouth” toward the sea. It encompasses the lowlands (area 4) with its western “arm” extending from the coast northeast over the Vasilikos lowlands. In the Vasilikos valley the north to south extent of area 3 is never greater than c.2.0km; however, as area 3 progresses east toward the Ayios Minas, the chalky-marl geology opens to the north and south extensively c.9.0km at its greatest extent.

The structure of the overlying soils is also markedly dissimilar between the two valleys. The overlying soils west of the Vasilikos river is a mixture of pockets of highly fertile cambisols, moderately fertile regosols and leptosols and marginal calcisols. East of the Vasilikos river and up to the western bank of the Ayios Minas River, soils are less diverse with one massive fertile cambisol deposit bordered by and containing islands of regosols and gypsisols. The massive cambisol deposit runs northeast from the coast between the two rivers through areas 4 and 3 up to the border of area 2 in the Ayios Minas valley. On either side of its coastal presence are two calcisol/luvisols deposits. This fertile zone would have functioned as an oasis of cultivable soil within what is otherwise a desert of marginal rubble-laden soils. It is in the marginal pockets of soil surrounding this fertile zone that settlements would have likely have been founded and where interaction between the valleys may have occurred early on. It is possible that the evidence for settlement identified in the informal survey to the north may extend down to this fertile zone and should be earmarked for investigation.

Pre, Early and Early Middle Bronze Age

Recorded Sites

It is in area 3 that for the first time we can compare recorded sites across the two valleys as the VVP and MVASP both surveyed the midland/lowland interstice.

Vasilikos Valley

Pre and Early BA

The north of area 3 in the Vasilikos valley was settled as early as the late Chalcolithic (c. 2700-2400 Cal. BC) again demonstrating a long history of economic viability across socioeconomic and technological regimes in this area. The settlement Kalavassos-*Argaki tou Yeoryiou* was established on the western side of the Vasilikos river near the border with area 2 (Figure 32, 37) before being abandoned in the middle BA. At this early stage in the valley’s prehistory, settlements were spread throughout the valley with between 1.2-2.2km distance between them at any given point suggesting some degree of communication and possibly integration existed along the entire valley.

Earlier Middle BA
Slightly later in the earlier part of the middle BA, four sites are established and abandoned in area 3 including Kalavassos-*Perivolia I* located on the western riverbank c.0.3km south of area 2, Kalavassos-*Perivolia II* c.0.5km east on the opposite side of the river, Kalavassos-*Kaoukkos* roughly 0.5km south on the west side of the river and Kalavassos-*Argaki East* a further 0.5km southwest (Figure 32, 37). These sites are generally situated on the western side of the river and are located on marginal soils adjacent fertile varieties. The western bias may support the presence of a western route along the Vasilikos river and perhaps constitute early settlements from which the Kalavassos cluster emerged in a southern shift of settlement.

Ayios Minas Valley
Early BA to Earlier Middle BA
While less is known about settlement in the Ayios Minas valley, sites were established in area 3 sometime in the early BA and abandoned by the middle BA with the founding of the settlement of ***Maras*** located on the western side of the river approximately 0.6km north of the lowland border and ***Maroni village*** c.800m to the northeast across the river. These are the earliest known sites in the Ayios Minas valley and currently suggest that the Vasilikos valley may have been settled first. ***Three tombs*** that may comprise a single cemetery are located 0.5km north of the settlements while a *f**ourth separate tomb/cemetery*** is located 0.7km east on the eastern bank of the river. The presence of early settlement in area 3 suggests that it wasn't population pressure in the neighbouring Vasilikos valley that led to this settlements as settlement density is believed to have been relatively low across the region. As with settlement elsewhere, settlements were built on the less fertile regosolic and gypsisolic soils but within very close proximity to fertile cambisols of the riverbanks, the central portion of the study area and eastern Ayios Minas valley.

Despite occupying advantageous positions, the settlements of ***Maras*** and ***Maroni Village*** may have relocated to middle BA settlements situated some 1.5km southwest which in turn are 0.5km north of even later middle BA settlements hinting at a trend of slow movement south toward the Maroni complex and the Vasilikos valley lowlands over time. The continued investigation of the settlements along this trajectory and the intervening areas could clarify the transition from early to late middle BA settlement in the Ayios Minas and perhaps add to the story of the origins of the Maroni complex and its relationship to the Vasilikos valley settlements.

The ***cluster of tombs*** also provide an opportunity to test the theory that burial practices shift from communal cemeteries outside of settlements to within settlements over time, particularly as late BA tombs are also found amongst them. This shift is attested throughout the eastern Mediterranean and is correlated with an increased importance on private property and ancestor veneration. These tombs are useful proxies for understanding relative (or perceived) wealth imbalance among settlement (or within settlements) and by extension can test whether later BA settlement can be viewed as hierarchical or heterarchical. Central to answering these questions would be the identification of settlement(s) affiliated with these burials. Currently, all tombs including the late BA example are considered extra-settlement and so investigation in the surrounding area would be advisable.

Predicted Areas of Archaeological Potential and their Socioeconomic Implications
Vasilikos Valley
The predicted AoAP for the early BA and earlier middle BA is limited to an east to west oriented corridor that extends 0.65km west of the river and 2.0km east where it reorients 90 degrees south for 0.65km (Figure 34). Recorded settlement is found in 2/3rds of the AoAP so focus should be placed on surveying the eastern third, particularly its southern extent where it overlaps the more workable soils that were likely targeted in the early BA and earlier middle BA. Surveying this portion of the AoAP may yield early settlements between the two

valleys and clarify whether such sites might predate the middle BA and whether settlement in the Ayios Minas was seeded from the Vasilikos valley or elsewhere.

Ayios Minas Valley
In area 3 of the Ayios Minas valley AoAP present as a narrow strip along the western riverbank measuring c.1.3km north to south by 0.3km east to west (with further extension south into area 1) and two smaller areas ~0.2km^2 and ~0.01km apart effectively making it a single AoAP. Survey should prioritise the southern 70% of the strip and westernmost polygon as no known sites are present within them. In similarity to the AoAP in the Vasilikos, investigation of the western polygon can help flesh out the area between the two valleys and clarify whether this intermediary zone was populated this far north (we do see settlement in this area further south). Surveying the southern portion of the riverbank AoAP could determine whether settlement exists between the early/middle BA settlements of area 3 and later Maroni complex of area 4. Any such sites would help clarify whether the earlier sites of area 3 contributed to the founding of the Maroni complex.

Late Middle and Late Bronze Age
Recorded Sites
Vasilikos Valley
Later Middle BA
Nine additional sites founded in the middle BA continued to be occupied into the late BA and possibly into the subsequent Iron Age (Figure 33, 37). The settlement of Kalavassos-*Draconikiaes* is located ~0.65km east of the eastern bank of the river roughly halfway down the area while the remaining eight comprise the Kalavassos cluster that includes the primary settlement of Kalvassos-*Ayios Dhimitrios* as well as the settlements of Kalavassos-*Mitsingites* and Kalavassos-*Pidieri* (with tombs), Kalavassos-*Khorapheri/Vounaritashi*, Kalavassos-*Argaki*, Kalavassos-*Latomari/Argakia*, Kalavassos-*Skhisti Petri*, Kalavassos-A*ndronikidhes* and Kalavassos-*Psoumadhes*. Kalavassos-*Ayios Dhimitrios* has received considerable attention*,* however the relationship of the surrounding sites is less clear, specifically whether they constitute individual settlements or are what has been termed a “mega-site” (Knapp 2013). Some villages implicated in these megasites such as *Khorapheri/Vounaritashi* may better be described as districts and contain evidence for a wide variety of products and services including copper and subsistence goods.

This cluster of sites does have access to some small deposits of fertile soils; however, they are clearly not its primary focus as a much larger deposits are associated with other sites to the east. Evidence from Kalavassos-*Ayios Dhimitrios* emphatically demonstrates it was an unparalleled and exceptional urban settlement containing evidence for industrial olive oil production and storage, industrial copper production, monumental architecture, complex administration in the form of seals and many examples of prestige goods from fine table ware to gold and faience objects (Knapp 2013). Half of the surrounding settlements are situated to the north between the primary centre and copper deposits with several more to the east at the margins of the fertile soil demonstrating a significant infrastructure focused on the influx of copper from the north and subsistence surplus from the southeast. The net result of this influx was the export of raw processed copper and copper objects as well as olive oil and other related goods destined for the coast as exports and potentially inland in exchange for raw resource acquisition.

That some of these settlements also contain tombs within their borders demonstrates the shift to intra-settlement burial taking place in the later middle to late BA and the movement toward a greater emphasis on private property (Halstead 1989), individual or smaller group competition through prestige market participation, attempts to control space through ancestral veneration and a greater emphasis on wider exchange and trade in line with the increase of social (and political) hierarchy occurring elsewhere on the island.

Ayios Minas Valley
No later middle BA sites recorded in area 3 of the Ayios Minas valley continued into the late BA, however the late BA tomb mentioned earlier, late BA Maroni complex in the south and some late BA material observed during the ground survey to the north demonstrate that settlement not only continued but flourished.

Late BA
Vasilikos Valley
One settlement (Kalavassos-*Kopetra*) and one cemetery (Kalavassos-*Mangia* Tombs 7 and 8) were established in the late BA in area 3 of the Vasilikos valley (Figure 33) with the settlement located ~0.35km east of the river at the border with the lowlands (area 4) and the cemetery ~0.3km further east. It is probable the interments are linked to the settlement though whether they are internal or external is unclear. It would be useful to determine whether the settlement and cemetery are connected or whether this is a rare example of a late BA extra-settlement burial. Unlike settlements further west, Kalavassos-*Kopetra* did not survive the late BA and was abandoned with its inhabitants probably joining the Kalavassos cluster. Most sites in the Kalavassos cluster seem to have transitioned from late BA to Iron Age with some degree of disruption linked to the breakdown of many of the exchange and trade routes they had come to rely on outside of the island.

Ayios Minas Valley
A single tomb is recorded for the late BA in area 3 of the Ayios Minas valley ~0.3km east of the river amidst the early to middle BA tombs. This demonstrates an area repeatedly selected for burial throughout the entire BA despite the shift from extra-settlement cemeteries in the earlier BA to burial within settlements by the late BA. No known late BA settlement is in the vicinity of this tomb nor are there recorded late BA components in Maras or Maroni village settlements to the south. This either suggests a potentially rare example of extra-settlement late BA burial or the existence of a yet unknown settlement. Interestingly the closest known late BA settlement 3.5km to the southeast suggesting there may very well be a late BA settlement closer by.

Predicted Areas of Archaeological Potential and their Socioeconomic Implications
Vasilikos Valley
In late BA Vasilikos valley c. 65% of area 3 (or $2/3_{rds}$ of its southern extent) is considered an AoAP with an east to west extent of c.9.0km and north to south extent of 1.0km (Figure 35). The two areas of most notable expansion include the southern portion of the Kalavassos cluster itself and the area west of the cluster down to the coastline. The Kalavassos cluster has many aspects that require further clarification, but most necessitate invasive excavation rather than the surface level examination proposed by the predictive models in this study. That said, focus should be placed on the southwestern portion of the AoAP between the site of Kalavassos-*Ayios Dhimitrios* down to the coastline as it contains no known sites and may reveal settlement organised around coastal resources such as fish, salt, and location-based benefits such as the abundant maritime trade accessible here rather than fertile central lowland soils and upper midland copper.

An additional AoAP of significance is the large ~3.3km projection from the main AoAP into the northeast into the Ayios Minas valley. This AoAP overlies a large tract of marginal soil within the greater fertile deposit of the inter-valley zone. This location would have provided access to fertile soils without compromising yields and to the settlements and resources of the Ayios Minas valley. This area should be investigated as it has not been surveyed and occupies the most likely area for settlement linking the two valleys to exist given the prime soils. Settlement in this area would have been well positioned to transport goods and materials between the two valleys, particularly copper but also cultivate subsistence surplus for centres engaged entirely on production of non-food items.

Ayios Minas Valley
Area 3 in the late BA Ayios Minas valley is also predicted to have experienced significant demographic expansion, though to a lesser extent than in the Vasilikos valley. Four late BA AoAP were identified. Three of these are small, isolated clusters that may indicate discrete sites while the fourth is significantly larger and extends northeast to southwest connecting area 3 of the Ayios Minas valley with areas 3 and 4 of the Vasilikos valley (Figure 35).

Future research should focus on identifying archaeological sites in this larger AoAP as it contains no recorded sites in its northern extent and provides a reasonable area from which to identify settlement that connects the two valleys, perhaps clarifying how the valley inhabitants interacted, particularly the representatives of their respective "primary" centres in the lowlands. The small clusters may represent individual villages located on the sparse fertile river soils (in the northernmost case) and marginal soils adjacent the large fertile deposit in the remaining cases. These AoAP may help locate settlement on one of the few portions of northern area 3 where the production of subsistence surplus might have been possible. It is from these hypothetical settlements that subsistence surplus might be supplied to any settlements focusing on non-subsistence production. All AoAP have the potential to possess settlements containing copper. Any examples will help clarify whether copper was coming through the area (and down to the Maroni complex and port system) and to what extent it was local or from the neighbouring Vasilikos valley. If copper is scarce then perhaps copper arrived in the Maroni complex through the lowlands.

Provisional Placement of Sites and AoAP in Knapp's Settlement Hierarchy
Sites in area 3 likely belong to "secondary" and "tertiary" categories in Knapp's (2013) social model and would serve various roles including ceremonial/distribution functions, some cultivation of subsistence crops and perhaps ceramic production as well as production and transport of copper ingots (the final state of raw copper for export) to the coast (Figure 36). Those closer to the coast would have been involved in the acquisition and processing of coastal resources and potentially high input but lucrative cultivars such as olives, other tree crops and deciduous vegetables.

7.4.4 Area 4: Mixed Geology-Marls and Fertile Alluvial Soils
The valley lowlands (area 4) comprise a coastal plain that runs from the midland/lowland interstice (area 3) to the coastline. It is dominated by the alluvial/colluvial deposits and the Apalos-Athalassa-Kakkaristra formation interspersed with pockets of chalky marl from the Pakhna and Kalavassos formations (Figure 31). The overlying soils are a mixture of fertile cambisols, less fertile regosols/leptosols and poorly fertile gypsisols. Despite the heavy mixing, the proportion of fertile to less fertile soils are far higher here than anywhere else in the study area, mainly due to the large proportion of fertile soils between the valleys.

The spatial distribution of these soils varies from west in the Vasilikos valley to the east in the Ayios Minas valley. The western lowlands in the Vasilikos valley are the least fertile with only a small pocket of fertile cambisols near the coast surrounded by less fertile regosols and leptosols. Moving east, the Vasilikos river comprises a corridor of fertile cambisols. The intervening area between the two valleys comprises a calcisol/luvisols mix on the coast with a large cambisol deposit that runs northeast through areas 4, 3 and up to the southern border of area 2 in the Ayios Minas valley. The central-northern portion this fertile deposit contains three sizeable regosol/gypsisol pockets. The Ayios Minas River also comprises a corridor of fertile cambisols. Finally, the soil east of the Ayios Minas River is largely comprised of the regosol/leptosols chalky marl of the chalk plateau with a pocket of cambisols on the coast bordered on the northwest and southeast by two small pockets of regosol/gypsisols and calcisol/luvisols respectively.

Pre, Early and Early Middle Bronze Age
Recorded Sites

Pre, Early and Earlier Middle BA
Sites of area 4 can be compared across the two valleys as the lowlands were surveyed in each. The lowlands not only contain the primary centres of the two valleys, Kalavassos-*Ayios Dhimitrios* and the Maroni Complex but also the oldest and longest-lived sites in the entire study area. The site of Kalavassos-*Tenta* for example was occupied for almost seven millennia from the Aceramic Neolithic to the Roman era (Figure 32, 37).

Vasilikos Valley
The earliest sites in Vasilikos lowlands (area 4) include the settlements of Kalavassos-*Kafkalia VI* ~1.1km west of the river near the border to area 3, Kalavassos-*Vasilikos River Bridge Site* slightly south on the eastern bank of the river, the settlement of Kalavassos-*Tenta* ~0.3km northwest*,* the settlement/cemetery/tomb of Kalavassos-*Ayious* 0.35km further east, the settlement of Kalvassos-*Pamboules* 0.7km southeast, the settlement of Kalavassos-*Kafkalia A* a further 0.6km southeast and the settlement of Mari-*Mesovouni* 1.5km southwest along the river (Figure 32, 37). The burials associated with *Ayious* are communal and lack any indicators of wealth disparity suggesting a lack of preoccupation with distinguishing individuals in death (Knapp 2013: 217-18). Most of these sites contain Aceramic and Ceramic Neolithic/Chalcolithic components that date to c.7000-4000 Cal BC and perhaps earlier.

Some of these settlements were occupied into the Roman period while others, despite being advantageously situated were abandoned in the middle BA (i.e., *Ayious*). Those abandoned are within 250m from successor sites suggesting that settlement drift to more advantageous locations or a merger with later middle BA sites is likely. As in area 2, early settlements were established on both fertile and marginal soils but always within 100m of workable soils amenable to domestic-level subsistence farming using hand actuated plough technology. Settlements are well distributed throughout the northern 2/3rds of the area with an emphasis on the east side of the river. Early sites may exist further south but are probably buried beneath deposits of alluvial/colluvial soil that in some areas may reach 25m deep.

The highly mixed soils of the central and western Vasilikos valley lowlands would have permitted inhabitants of these early settlements to experiment with the more workable and less fertile regosols as well as the heavier clay-rich fertile soils. The longevity of some of these sites further supports the idea that this geological context is the most desirable locale in the study area.

Ayios Minas Valley
Though formally surveyed, no sites predating the middle BA have been recorded in the Ayios Minas lowlands. While earlier components may exist under colluvial/alluvial deposits, it is also possible that lowland settlement in the Ayios Minas emerged later than in the Vasilikos valley, perhaps only when the logistical requirements of a tiered settlement system necessitated the establishment of administrative, production and export-oriented sites associated with the later Maroni complex.

Earlier Middle BA
Vasilikos Valley
Within the first half of the middle BA, nine sites are established and subsequently abandoned along the length of the lowlands of the Vasilikos valley (Figure 32, 37).

- In the north, the three settlements of Kalavassos-*Kafkalia I-II*, Kalavassos-*Kafkalia III* and Mari-*Kalotsikous* are located along the border of area 3 within a 0.5km^2 cluster. The two northern settlements may indicate two phases of the same occupation with *Kafkalia III* being later. These settlements were established on less fertile soils but well positioned between the primary centre and the fertile cambisols of the western and central valley and poised for (if not already undertaking) the intensification of cultivation in support of the Kalavassos complexes that themselves were focused on the intensive production and administration and export of copper and olive oil.

- Midway down the area, a second "group" of three sites is found along a 1.3km line extending from the river southeast into the large fertile deposit between the valleys. Eastward along the river are the settlements of Kalavassos-*Krommidhia* and Kalavassos-*Kafkalia C* located on a marginal leptosol/calcisol pocket bordering the fertile cambisols and the settlement/tomb of Tochni-*Mouthkia* a further 1km out into the fertile cambisols. The two eastern settlements may also be two components of a single settlement and were founded at the fringes of the cambisols presumably to access the high-input but high-yield or lucrative cultivation that the soils afforded. The purpose of settlements further east is less obvious as they appear well out into the fertile soils or closer to the Ayios Minas River than the Vasilikos. This may suggest either that they were established to reduce the distance between the valleys and increase interaction or their inhabitants originated in the eastern Ayios minas valley.

- In the south, ~1.0km inland from the coast, are the settlements of Kalavassos-*Loures* and Mari-*Kremmos tou sani/Livadhia* which are both settled on marginal soils with the former ~0.3km from the large fertile deposit and the latter adjacent the fertile soils of the river. The two settlements are sufficiently distant to be considered separate occupations, though *Kremmos tou sani/Livadhia* may represent slightly later settlement.

- Two additional settlements, Tochni-*Petreli* and Tochni-*Petreli North* were identified by the VVP (Todd 2013) survey but are technically 0.5km closer to the Ayios Minas River than the Vasilikos. They were established on the western fringes of a pocket of marginal soil that border the far eastern side of the large cambisol deposits. Why this location was chosen can be interpreted in several ways. If the settlers originated on the Vasilikos side, it suggests that occupation was too dense and necessitated travel closer to the Ayios Minas valley, perhaps with the incentive to increase exploitation and interaction with a separate valley system. If they had originated from the Ayios Minas side then they, like other villages in the Vasilikos valley, settled on the fringes of marginal soil as close to the fertile soils as possible to most efficiently exploit soil profiles for cultivation.

  Regardless, the settlements raise interesting questions including from where, if from the Ayios Minas valley, did they originate? The only links that are possible given current data are the earlier settlements of Maras and Maroni village to the northeast or contemporary settlements of the Maroni complex to the southeast. It is possible that the *Petreli* settlements were established to support the Maroni complex as either an intermediary between valleys, a source of subsistence or perhaps both. The abandonment of the *Petreli* settlements in the middle BA is puzzling as they seemingly occupy an advantageous position with little competition, however, around the time of abandonment a new settlement 200m south is founded suggesting a drift or purposeful relocation probably occurred. This is certainly an area that requires further research to clarify these potential relationships.

Interestingly, while all settlements of the Vasilikos lowlands lack a late BA component (except for a port discussed below), most show evidence for reoccupation in the Iron Age. However, this may have occurred following some disruption to the settlement hierarchy due to external disruption to trade and exchange routes and by extension the means to build status and exert influence and power. No recorded Ayios Minas lowlands settlements possess an Iron Age occupation.

Ayios Minas
Settlement in the Ayios Minas lowlands is more diffuse than in the Vasilikos valley, however the number of settlements relative to area of reasonably fertile soils is similar. The reason for a lack of early BA settlement in the Ayios Minas lowlands is less clear, particularly in the west where good soils combine with freshwater and coastal resources to provide a relatively superior base upon which to thrive. It may simply be that at this early-stage population density was sufficiently low that valley occupants had the choice to settle the more fertile area 3 in the Ayios Minas valley and the Vasilikos valley. Only in the later middle BA when population density increased, and socioeconomic circumstances necessitated a coastal processing / administrative / production centre and port were the lowlands "settled".

Predicted Areas of Archaeological Potential and their Socioeconomic Implications
Vasilikos Valley
In the Vasilikos valley lowlands the predictive model of the pre, early and earlier middle BA produced a ~3.5km east to west by 3.0km north to south ovoid shaped AoAP situated in the middle of the area with a bias to the eastern bank of the river. Projecting from the southeast of this an additional corridor shaped AoAP extends ~2.0km east toward the Ayios Minas valley. Additionally, there is a sliver of AoAP along the coastline extending west from the river for ~2.0km (Figure 34).

The central and north-western portion of the main AoAP contains many sites, some of which have been thoroughly investigated so priority for research should focus on the southwest that lacks sites. It is possible that early BA and earlier middle BA will be found on the less fertile soils here and/or settlement exploiting coastal resources and conducting activities that support the port by facilitating transport and potentially exchange in the form of markets. By contrast, the portion of the AoAP that projects out toward the Ayios Minas as a corridor is entirely within fertile soils, contains no known sites and occupies an interesting liminal zone between valleys. While this appears promising, locations found entirely within highly fertile soils have overwhelmingly proven devoid of settlement throughout most of the BA. The sliver of AoAP located along the coast should be explored as it contains a late BA port. Investigating this area may provide an earlier component that could clarify the origins (if they are earlier than the late BA) of maritime oriented trade in the valley.

Ayios Minas Valley
In the Ayios Minas valley four AoAP were identified by model 2. One consists of a ~1.7km long by 0.25km wide strip ~0.25km from the western riverbank that runs from the coast to the boundary of area 2. Attached to this strip and running perpendicular to the east (crossing the river in the process) is another strip ~0.2km wide and ~1.3km long. A third AoAP oriented northwest to southeast runs parallel to the river on its eastern bank and measures ~1.0km long by 0.15km wide. Finally, a sliver of AoAP along the coast runs from the eastern study area boundary toward the "Maroni Complex" for ~0.7km. These AoAP are probably all indicating the location of one to two sites.

These AoAP should be subject to intensive survey due to their small size, their lack of known sites, their physical connection with AoAP in area 3 and between the early sites of Maras and Maroni Village and their situation on less fertile land adjacent fertile soils ideal for settlement throughout the BA. Survey here may help clarify the circumstances surrounding the founding of the Maroni complex (i.e., organic growth out of the domestic subsistence farmers of the valleys, from a foreign element or some combination of domestic ingenuity and foreign influence) including clarification of the relationship with the earlier sites a few kilometres to the northwest.

Later Middle BA and Late Bronze Age
Recorded Sites
Later Middle BA
Fifteen additional sites were established in the middle BA that remained occupied into the late BA and later in the lowlands across the two valleys (Figure 33, 37).

Vasilikos Valley
Recorded settlement established in the later middle BA are largely confined to the northern half of the lowlands within two areas.

- Central northern cluster along the boundary with area 3 measuring c.1.5km^2 with a bias toward the western side of the river. This cluster contains seven sites including the impressive primary settlement of Kalavassos-*Ayios Dhimitrios,* the settlement of Kalavassos-*Kafkalia IV* ~100m west, the settlement of Mari-*Matsounin/Mandra tou Rirou* 0.5km southwest*,* the settlement of Mari-*Skeli II* 0.5km west and the settlement of Kalavassos-*Kafkalia V* 0.5km north which all reside on the west side of the river. Seven hundred metres east of *Ayios Dhimitrios* on the east side of the river are the settlements of Kalavassos-*Sirmata* and Kalavassos-*Ayios East*, the former of which contains tombs.

  This group is effectively part of the large cluster in area 3 forming the Kalavassos complex or "mega-site" (Knapp 2013: 351). These settlements, particularly those on the west side of the river are the closer of the cluster to fertile soils and may have been responsible for the provisioning of the primary centre with subsistence surplus. The two settlements on the east side of the river by contrast reside on fertile soils and were either focused on high-input prestige goods such as olives and other tree crops or on the provision of subsistence surplus for the primary centre. Answering these questions definitively requires intensive survey and probably excavation.

- One-kilometre southeast of the Kalavassos complex midway down the lowlands is a southwest to northeast oriented line of three settlements including the settlement/cemetery of Mari-*Paliembela* and settlements of Kalavassos-*Kafkalia B* and Kalavassos-*Kokkinoyia* which are both 0.5km apart to the northeast. These settlements were almost certainly engaged in the cultivation of the sizable fertile deposit of the inter-valley region and occupy less fertile pockets of soil next to these highly fertile areas. Except for a late BA port on the coast, these settlements comprise the southernmost occupation in the later middle to late BA, however this may be due to the significant accumulation of alluvial/colluvial deposits in the coastal half of the lowlands.

Ayios Minas Valley
Later Middle BA
Five settlements were established in the Ayios Minas lowlands in the later middle BA. Four of these comprise the founding settlements of the Maroni complex and are located within a 1.5km^2 cluster adjacent the coast on the east side of the Ayios Minas River. The four include the "primary" settlement/port of Maroni-*Tsaroukkas and Maroni*-Vrysoudhia on the coast and the settlements of Maroni-*Kapsaloudhia* and Maroni-*Aspres* ~0.5-1.0km inland. The sites of the Maroni complex have been thoroughly investigated yet the relationship between them and more northern sites of the valley identified during informal survey by the author and the primary centre of the neighbouring Vasiikos valley remains unclear. Both the Vasilikos and Ayios Minas complexes were established in the middle BA but to what degree this relationship was hierarchical, heterarchical or non-existent is uncertain. One compelling view

is that the two operate as components within a broader hierarchical system in which Kalavassos-*Ayios Dhimitrios* handled administrative, production and ceremonial activities while the Maroni complex was more commercially oriented due to its port (Knapp 2013). It is likely that survey will not answer this, however recording further sites between the two will help flesh out lowland settlement patterning and excavation may produce items indicating extent and perhaps particular locations with which they interacted.

The fifth site, Tochni-*Mesovouni* is a settlement located midway between the two rivers some 3.2km west of the Maroni complex and 1.5km inland from the coast and could have served to bridge the primary centres of the valleys. While few such "bridge" sites existed at any given time, this region was occupied to a degree as far back as the pre-BA. Investigating the early stages of inter-valley settlement could clarify the circumstances under which the valleys interacted over time. Of particular interest is the surrounding *Mesovouni*, the *Petreli* sites to the north, the early BA settlements of Maras and Maroni village and intervening marginal soils.

Late BA
Vasilikos Valley
Despite the fluorescence of economic activity in the lowlands of the Vasilikos valley during the late BA, all recorded settlements were in fact established by the end of the middle BA (Figure 33). The settlement of Tochni-*Lakkia* is situated on the western bank of the Vasilikos river along the coast and was probably a port town that saw to the more distant commercial interests of Kalavassos-*Ayios Dhimitrios* but probably served as a more informal market hub as well. *Lakkia* is of great importance as it demonstrates a significant investment in transport and exchange infrastructure to and from the valley that increases the likelihood that a coordinated elite group or perhaps coalition was taking an active role in the socioeconomics of the study area and beyond in the late BA. The location of two ports within ~5.0km of one another (the other in the Maroni complex) is interesting and has important implications for understanding the relationship between the primary centres as the need for two ports operating within a single settlement system and in such a small area is seems counterintuitive. Whether they were competitive or cooperative is a distinction that needs ot be investigated.

Ayios Minas Valley
Two late BA settlements are recorded within the Maroni complex cluster in the lowlands of the Ayios Minas valley. Maroni-*Yialos* is located on the coast and may represent a port while Maroni-*Vournes* is hypothesised as being a primary centre and is located 0.5km inland. It is unclear if the 5 settlements of the Maroni complex are contemporary or represent the shifting population, specifically as both later middle BA *Tsaroukkas* and late BA *Yialos* are considered ports sites. It is uncertain whether the Maroni complex competed with, co-operated with or operated alongside the primary centre of Kalavassos-*Ayios Dhimitrios* in the Vasilikos but answering this probably relies on the specific roles these ports played in valley socioeconomics.

Predicted Areas of Archaeological Potential and their Socioeconomic Implications
In the later middle BA, many new settlements appear. Most can be explained as the result of a shift of their early BA predecessors closer to fertile soils or into the sphere of influence of the larger primary urban centres that were emerging at the time. The "primary" centres of Kalavassos-*Ayios Dhimitrios* and potentially the Maroni Complex were established in the later middle BA and came to comprise the focal point of valley wide socioeconomics. To what extent this emerging system was hierarchical is debated but the appearance of monumental architecture, large size, possession of industrial-level production and other accoutrements of central places suggest that power and authority was centralised in these primary centres, though not necessarily in the hands of a very few.

It was throughout the middle BA that settlement expanded, the exploitation of native copper for intra-island and international markets fluoresced and settlement reoriented itself into clusters and possibly hierarchical tiers along the Vasilikos valley (Figure 36). These circumstances were largely in full force by the later middle BA, and it was at this time that settlement both expanded and reoriented itself to take advantage of the bustling inter-island and maritime trade that was already developed in the eastern part of the island. By the later middle BA to early late BA the settlement complexes surrounding Kalavassos-*Ayios Dhimitrios* and the Maroni-*Vournes* would have had some authority over the mining, production and transport of copper, the agricultural production and processing of certain capital-intensive crops such as olives and functioned as administrative and transhipment points for these products (Knapp 2013: 357).

By the late BA, expansion had reached its maximum and it is argued that most valley inhabitants were operating under the economic influence exerted by the primary centres (Keswani 1993) and some evidence exists that they may have controlled inland administrative centres, coastal ports and several inland settlements occupied in copper extraction/processing, farming, ceramic production, and many other extractive and processing activities. Port settlements were established to tap into existing eastern Mediterranean exchange routes that traversed the southern coast of Cyprus

Vasilikos Valley
By the late BA ~90% of Vasilikos valley lowlands comprise a single AoAP (Figure 35). The AoAP is centred on the river, extends roughly 2.4km east and 2.8km west from its banks and occupies the entire area south from the midland/lowland interstice to the coast. Potential areas of future research include the AoAP found between present-day Mari village and the Vasilikos river as it contains no recorded sites and may produce settlements in the under-represented southwest of the valley in general and specifically those that focused on exploiting coastal resources. A second area of interest is the coast. Recently, high rates of coastal erosion have exposed port sites dated to the late BA. Future work should include a more thorough coastal survey (west of Tochni-L*akkia* in the Vasilikos valley) to reveal the origins, extent and function of these sites and their role in exchange throughout the study area and in status building and alliance construction by elites as well as any support villages in their vicinity. A final area of interest are the locations of long-lived sites within the late BA AoAP. One such area that may contain sites that span the entire BA is that immediately surrounding the power plant on the coast as marginal soils surround a pocket of fertile soils, a configuration that has tended to contain long occupied settlements in other areas.

Ayios Minas Valley
As in the Vasilikos valley, the Ayios Minas valley lowlands are largely covered by a single large AoAP except for two 1.5 km^2 areas either side of the river ~1.0km inland. It is unclear why these large gaps are considered of lower archaeological potential, but it is probably a combination of the soils' extreme infertility and the relatively low proportion of nearby fertile soils. Much of the Ayios Minas lowlands that are considered AoAP have been thoroughly surveyed or contain known settlements. However, due to the intensive and urban-oriented nature of the MVASP survey some areas could be further investigated. Specifically, a 1.5km^2 area in the southwestern portion of the Ayios Minas valley adjacent the west riverbank on the coast. This AoAP lacks known sites, contains marginal soil adjacent fertile soils that would entice settlers to build upon and resides at the nexus of the two valleys should be considered. It is possible that a second settlement (in addition to Tochni-*Mesovouni*) that links the valleys together resides here.

Provisional Placement of Sites and AoAP in Knapp's Settlement Hierarchy
Within Knapp's (2013) model, sites in the lowlands of the valleys could belong to both "primary" and "secondary" tiers (Figure 36). Inland sites would serve various roles including ceremonial/distribution functions, some cultivation of subsistence crops and perhaps ceramic

production as well as transport of copper ingots (the final state of raw copper for export) by those found closer to the Kalavassos cluster. Those closer to the coast would have been involved in the acquisition and processing of coastal resources and potentially high input but lucrative cultivars such as olives, other tree crops and deciduous vegetables. There is some debate as to whether the Maroni Complex might be considered as a spatially compressed version of Kalavassos-*Ayios Dhimitrios* and Tochni-*Lakkia* in the Vasilikos valley, though it has also been considered as serving a secondary role in support of the Vasilikos centre (Knapp 2013).

The proposed settlement hierarchy relies to a large extent on the fact that researchers have found it difficult to explain the existence of the primary centres without it, particularly given the presence of clear settlement hierarchies elsewhere on the island. It is also possible however that the relationship among settlements was heterarchical (as these settlements formed later than most on the island) and that while copper production for lowland consumption/exchange was important, emphasis was on a mixed strategy that dispersed opportunity through the exploitation of a plethora of economic resources including ceramics production, tree crops (olives and carob) cultivation, timber, charcoal, stone, salt, and fish that this area fosters. It is likely that socioeconomic relationships lay somewhere in between where power imbalances were not static through time but by necessity of many factors in flux. It is as difficult in the late BA to discard the possibility that over time different individuals, families, groups and coalitions were sufficiently savvy, fortunate, opportunistic, and intelligent about how they engaged with the economy in a way that would confer significant advantages over others and that these agents would create an imbalance in wealth and probably power and authority.

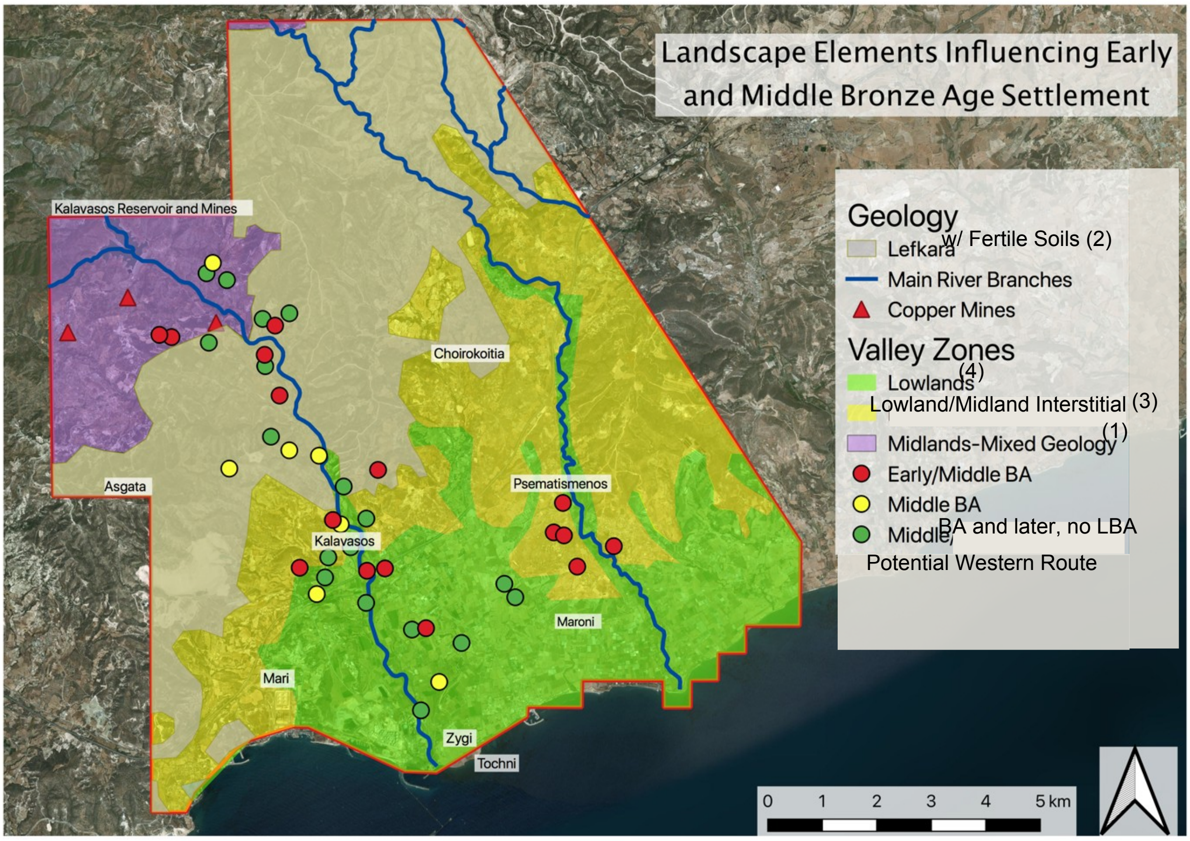


Figure 32: This map depicts the spatio-temporal settlement patterning of the early and earlier middle BA. Sites founded prior to or during the early BA, some of which were occupied into the late BA are indicated by red dots. Sites founded and subsequently abandoned in the middle BA are indicated by yellow dots. Sites founded and subsequently abandoned in the middle BA, have no late BA occupation but were reoccupied later are indicated by green dots. The valleys can be organised into 4 zones of occupation including zone 1: the cupriferous mixed geology of the upper midlands (purple), zone 2: the fertile river soils that bisect the Lefkara chalk plateau (beige with green corridor), zone 3: lowland/midland interstitial (yellow) and zone 4: the lowlands (green). Other notable elements that positively influence settlement include the copper deposits of the mixed geology of the northern midlands indicated by red triangles and potential western travel route along the Vasilikos river indicated as a red band. It is notable that while the mixed geology (in purple) is well represented in the Vasilikos valley portion of the study area, it is only sparingly represented in the Ayios Minas valley. Base map from Google Earth, https://earth.google.com/web/

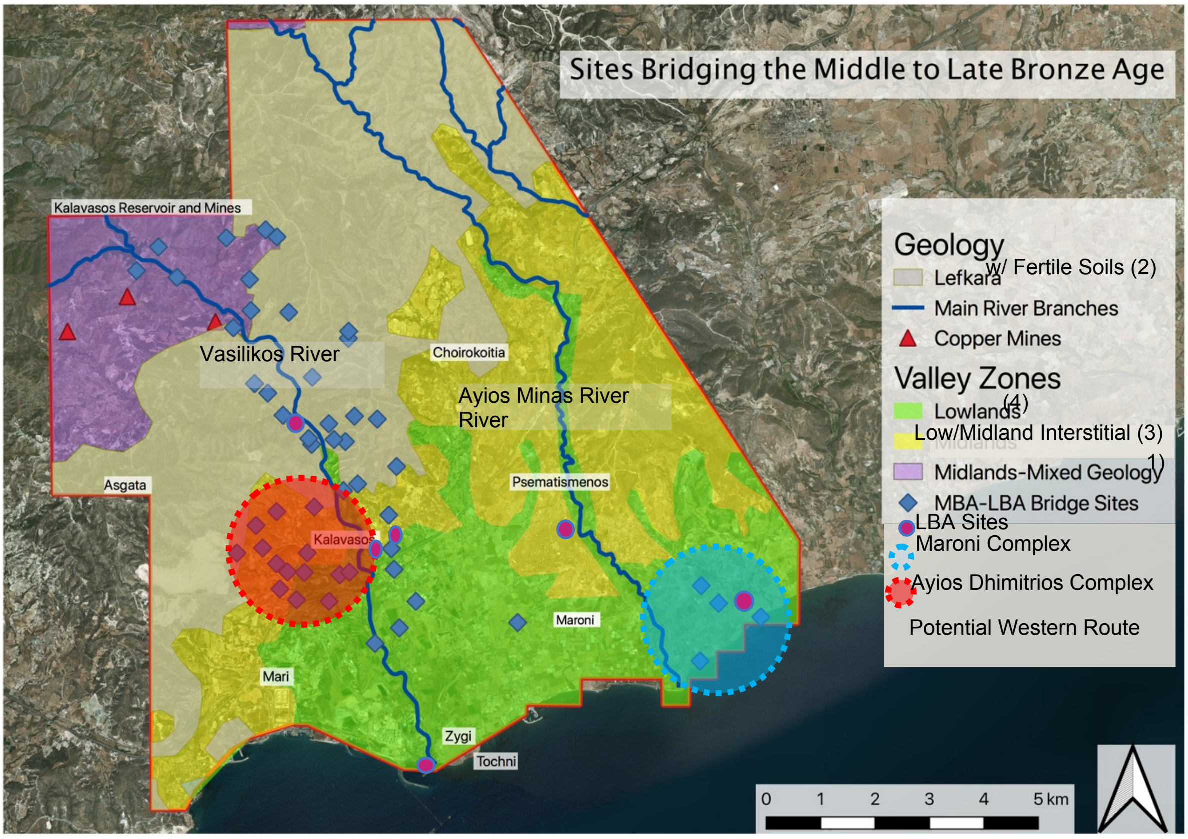


Figure 33: This map depicts sites that bridge the later middle to late BA, or more specifically those settlements founded in the middle BA (or earlier) that possess uninterrupted occupation into the late BA. The patterning of these sites largely aligns with that of the late BA suggesting that the socioeconomic and political conditions that synonymous with the patterning of the late BA were well under way in the later middle BA. Two clusters are of particular importance as they represent the foundations of the "primary" centers of Ayios Dhimitrios in the Vasilikos valley (in blue) and Maroni Tsaroukkas/Vournes (aka the "Maroni Complex") in the Ayios Minas valley that came to prominence in the late BA. As no survey was undertaken in the midlands of the Ayios Minas valley, the settlement structure of the early, middle and late BA will be inferred from predictive model results. It is notable that by the later BA settlement is equally distributed along both banks of the Vasilikos river rather than adhering to the western side that was arguably favored in the early/middle BA. It is also noteworthy that the lowlands are already showing a demographic expansion at this stage. Base map from Google Earth, https://earth.google.com/web/

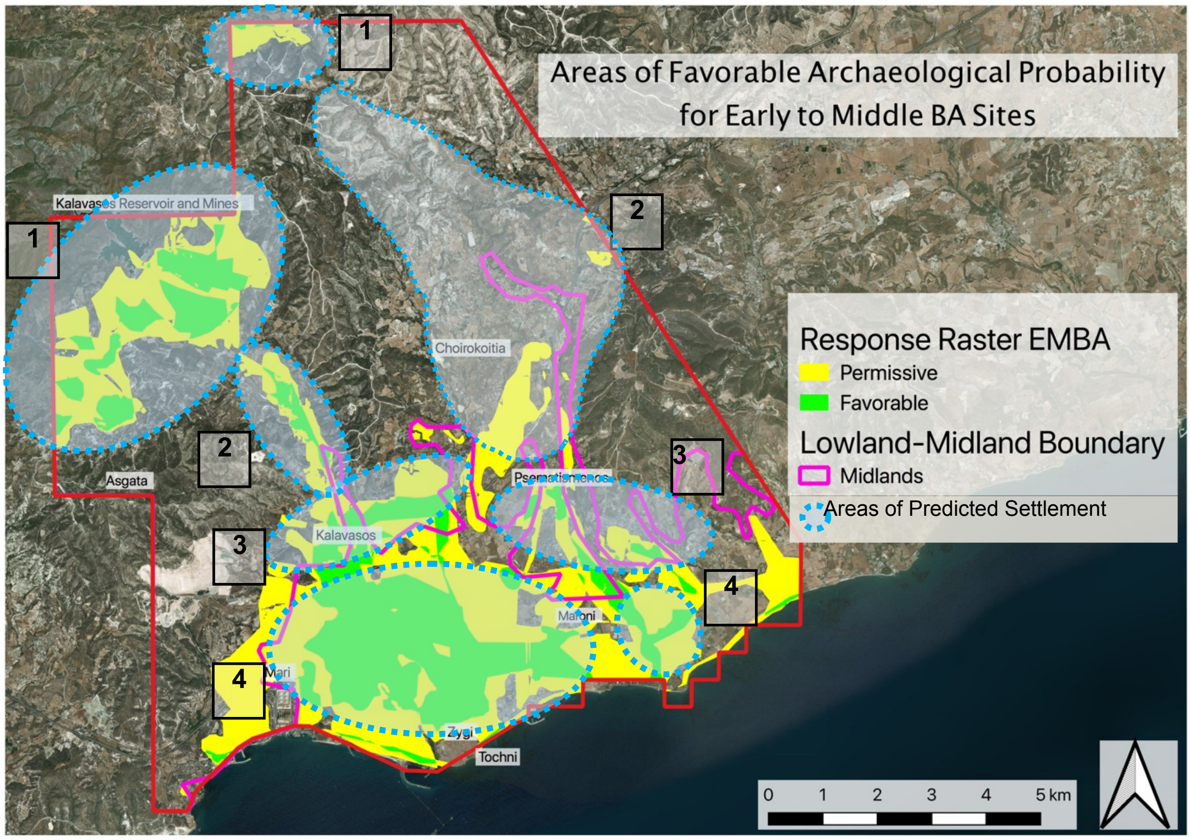


Figure 34: Four areas of analysis in each valley are depicted in the map above (outlined in dashed blue and numbered 1-4) totaling 8 prediction areas for the early and middle Bronze Age. Favorable areas, or those of highest probability (green) are distinguished by areas of permissive probability for containing archaeological potential (yellow). The boundary between fertile lowlands and hilly and chalk-rich midlands (magenta line) is for guidance. Base map from Google Earth, https://earth.google.com/web/

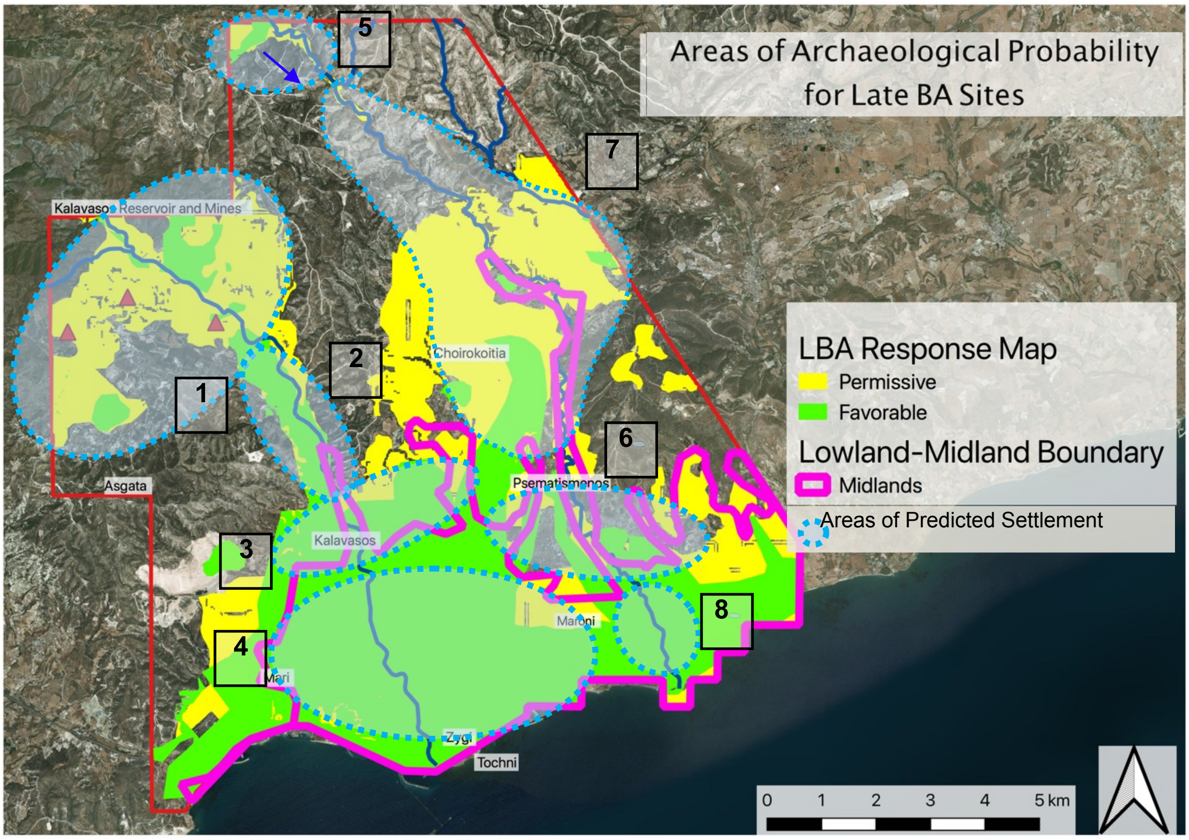


Figure 35: The six predicted areas of archaeological settlement for the early and middle Bronze Age (encircled by dashed blue and numbered 1 through 6) are superimposed on the late Bronze Age predictor map to illustrate areas of settlement that have expanded or contracted. Favorable areas, or those of highest probability (green) have contracted in the northern areas of mixed geology above the Lefkara chalk plateau but have expanded along the fertile river valleys cutting through the chalk plateau and the central lowlands, along the border of the lowlands and midlands and within the lowlands proper. There are two new areas of settlements as well; one stretching between Psematismenos to Choirokoitia villages into the chalk plateau and another along the entire coastline. The boundary between fertile lowlands and hilly and chalk-rich midlands is represented by the magenta line. Base map from Google Earth, https://earth.google.com/web/

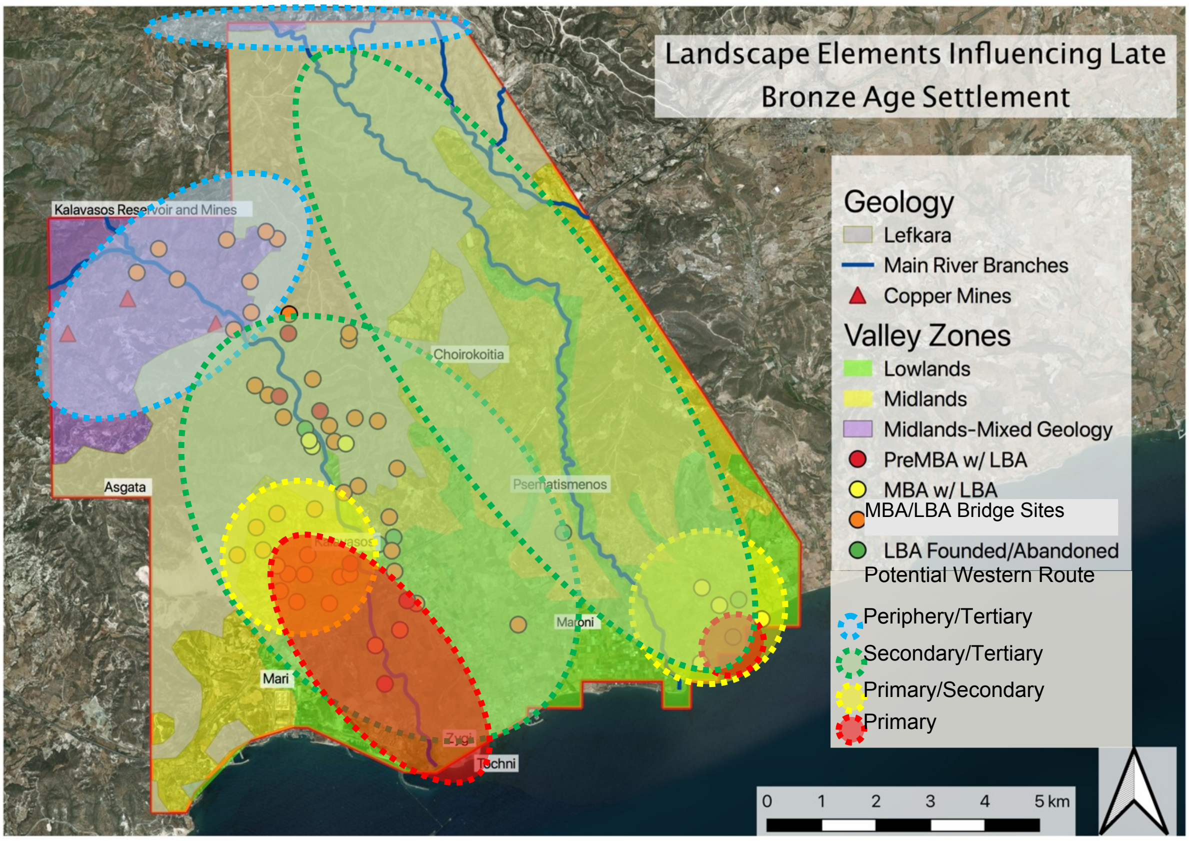


Figure 36: This map depicts the spatio-temporal settlement patterning of the late BA. Sites founded before or during the early BA that contain a late BA component are indicated by red dots. Sites founded in the middle BA and subsequently abandoned in the late BA are indicated by yellow dots. Sites founded in the middle BA that continued to be occupied into the late BA and later are indicated by orange dots. Sites founded and abandoned in the late BA a indicated by green dots. The zones of the valleys that have implications for settlement patterning are indicated by four colours, the cupriferous mixed geology of the upper midlands (purple), the Lefkara chalk and fertile Vasilikos river soils that bisect it (beige with green corridor), lowland/midland interstitial (yellow) and the lowlands (green). Elements that have a positive influence on settlement are more numerous in the late BA as the socioeconomic system became more complex as indicated by the spatial extent of settlement. Negative influences continue to be the Lefkara chalk plateau (beige) however the corridor of settlement afforded by the fertile river valley (green) remains and has increased in density, particularly along the Vasilikos valley north of Kalavassos. There is also a notable contraction of settlement in the mixed geology (purple with copper deposits indicated by red triangles) to the north of the Lefkara chalk plateau. This has been interpreted as a reduction in midland-oriented domestic farmers and replacement by copper-oriented settlements. Positive elements include the lowlands of both the Vasilikos and Ayios Minas valleys and the Pakhna geological formation (yellow) marking the midlands/lowland interstitial zone. The potential western route that is considered to have attracted settlement (red line) in the early and middle BA is less obviously influential as settlement is spread on either side of the river uniformly (Todd 2013). Finally, the site hierarchy levels as laid out in Knapp's (2013) "social model" are superimposed on the study area to generally position sites within the model. These are indicated as follows "periphery/tertiary" (blue), "secondary/tertiary" (green), "primary/secondary" (yellow) and "primary" (red). Base map from Google Earth, https://earth.google.com/web/

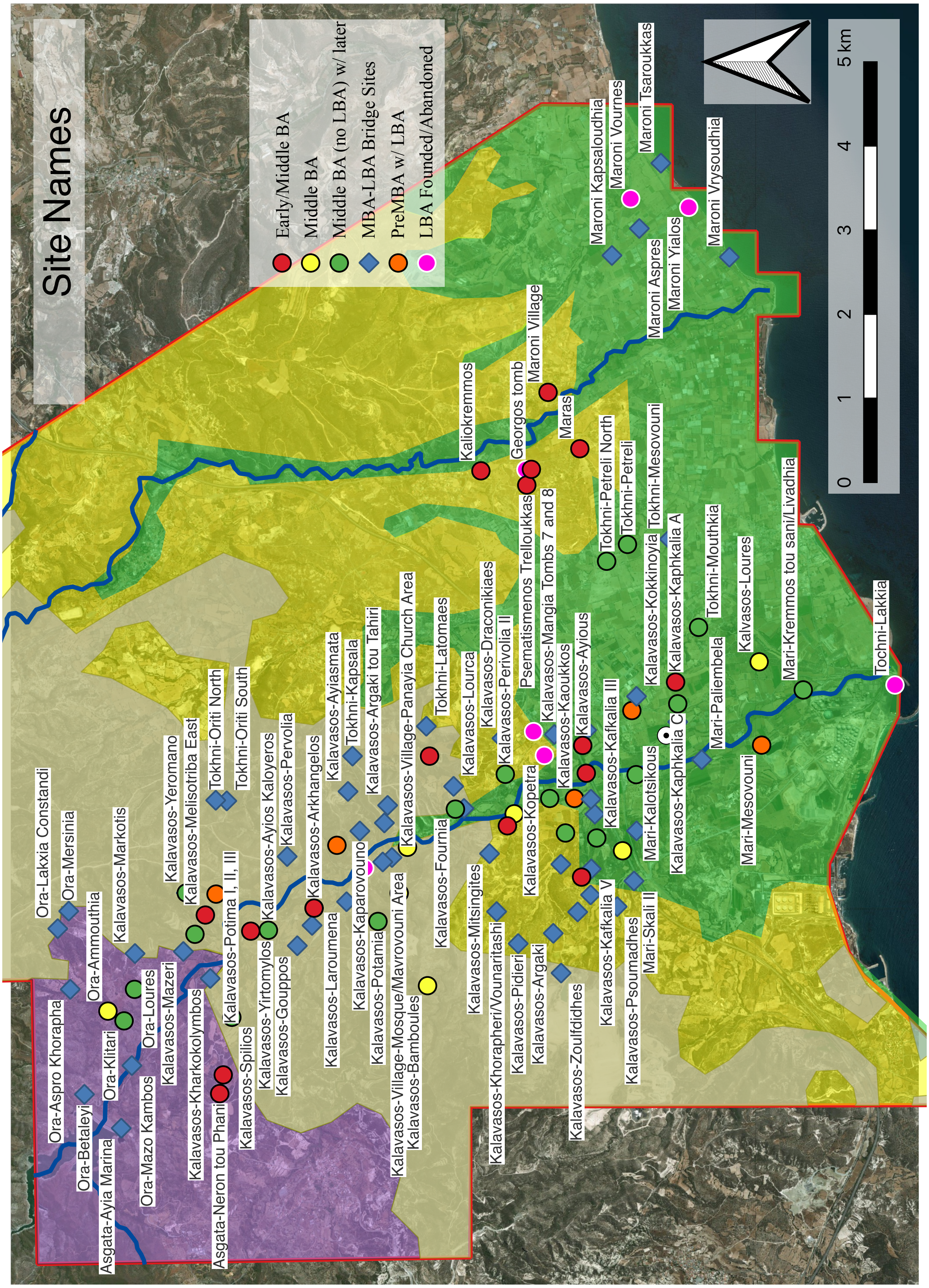


Figure 37: Names of recorded archaeological sites for BA. Base map from Google Earth, https://earth.google.com/web/

8: Summary and Conclusions

The weights of evidence (WoE) method for predictive modelling was employed in ArcGIS using the ArcSDM toolkit to predict areas of archaeological potential (AoAP) in the Vasilikos and Ayios Minas valley lowlands and midlands. The WoE method was built using a database of existing sites and their relationship to aspects of the environment to produce these AoAP. The method is particularly well suited to archaeological prospection in the study areas as it is believed that archaeological sites here have a high spatial dependence on geophysical and geochemical features, namely underlying geology, and overlying soil. The WoE method provides several advantages in handling uncertainty and bias and the results are amenable to independence, precision, and accuracy testing. The WoE method and the modeling results were used to address four main aims outlined in the introduction.

8.1 Aim 1: Addressing Uncertainty and Bias

Many sources of bias are present in the process of developing predictive models and in the procedures used to collect and organise the archaeological raw data. These phenomena detract from the precision, accuracy, power and validity of models and their data if overlooked or ignored. The WoE method aimed to address sources of bias general to predictive models and specific in the chronological and spatial biases of the data from the study area.

Measures taken to reduce the inherent bias and uncertainty present in the predictive modelling used in this study include the use of Bayes rule to address uncertainty in model data; subjecting model results to Kvamme's gain statistics to assess precision and accuracy of the raw data and the use of an iterative approach that enables the analyst to test whether evidential themes possess conditional independence and should be retained, combined with other themes, or abandoned. Measures taken to address the chronological and spatial biases unique to the study data include developing both low and high chronological resolution models (general, early/earlier middle BA and later middle/late BA) to address the disproportionate influence of the BA on recorded sites. This enables analysis of broader and narrower chronological issues pertaining to archaeological sites in across time and the BA respectively.

Measures taken to address the influence of the different spatial resolutions adopted by the two surveys that provided the source data for the models are built into the WoE method. In this study, the WoE method required that data from the two surveys be combined. By combining data from the intensive urban approach of the MVASP and the extensive rural approach of the VVP, the effects of each were offset such that the information learned by the model from the MVASP data (an intensive approach) would be applied to the context of the Vasilikos valley (which received an extensive treatment) and vice versa. An additional spatial bias introduced by the MVASP not surveying the midlands of the Ayios Minas valley meant that not sites from that region were included in the training set and therefore could not inform the predictive models. The VVP by contrast did survey the valley midlands and produced a record of sites that could inform the training set in the WoE model. It is believed that this inclusion could be used to identify sites in this region in the Ayios Minas valley based on the accepted premise that contemporary settlements in geologically similar contexts within proximity adhere to similar rules.

8.2 Aim 2: Produce a General Model of Archaeological Prediction

Models that lack high chronological resolution are unable to reconstruct finer aspects of settlement patterning but are useful for identifying general AoAP. Knowing where archaeology in general is likely to be found is valuable in academic and more prosaic contexts. While the focus on this study is on the BA, many academic research projects concern the long-term occupation of a region and can benefit from a predictor map that provides a diachronic perspective. Such maps can be extremely useful as a starting point for survey and save significant time and money in such campaigns. General predictor maps can also serve as important tools in the decision making by government, non-profit, and public sector stakeholders in decisions involving modern land use management. This is essential, for example, when laying the route for a motor way in a way that is least impactful on the heritage of a landscape or determining which areas would make good candidates for cultural heritage reserves.

The general predictive model (model 1) successfully highlighted 51km^2 of archaeological potential that should be carefully considered or avoided by developers and investigated by academic and government archaeologists. While not all AoAP are equally promising, roughly half of them identified in this study contain no known archaeological content and may contain new settlements, cemeteries, or other types of sites. Encouragingly, most of these AoAP have been earmarked for revisit by academics prior to the undertaking of this predictive modelling suggesting that academic opinion is aligned with model results.

In addition to these recommendations, further support that the predictive model was successful comes by way of the rich archaeological landscape identified by the informal ground truth campaign undertaken in the northern Ayios Minas midlands by the author. There are several observations that could generate informative and robust field projects in an unsurveyed area that was previously considered exceptionally marginal including a potential pan-BA settlement, a probable BA cemetery and a long-lived terrace-based cultivation system among several other isolated finds. These results could serve as the basis for a comprehensive survey project focused on the Ayios Minas midlands. Any recorded sites resulting from such a project could be used to improve the predictive power of the models featured in this study.

8.3 Aim 3: Modelling Bronze Age Settlement Patterning and Socioeconomics

The third aim addresses five important questions regarding BA settlement patterning and socioeconomics in the study area. The BA was selected as it has long been the focus of research in the study area and was the subject of two ground surveys that created a robust catalogue of recorded sites and background research that can populate models and contextualise their results. Some of these questions are concerned the belief that important changes occurring around the middle of the middle BA, particularly the transition from millennia-old household-oriented agro-pastoral subsistence farming focused on growing crops and raising livestock to a centralised economy heavily invested in capital-intensive (high-input for high-financial gain) goods such as copper and olives for export into international markets. To predict where archaeological sites fall along this transition might appear, two models were created that split the BA in two. The recorded sites and resultant AoAP of these two models were analysed in the context of prevailing theory to better consider and understand the relationship of settlement patterning to socioeconomic change over time.

i. *Where might the early BA sites that have eluded archaeologists be found?*

One puzzling characteristic of the study areas archaeological record is the lack of early BA sites. The reason for this is unclear, though their absence has been linked to an inability of archaeologists to identify signature materials unique to the period, which means that while settlements from this period exist, and possibly have even been observed, they have not been definitively identified and recorded. On the other hand, it has also been suggested that early BA settlers dispersed into the north, lived mobile and ephemeral lives, or left the valley entirely for a time. While the predictor map resulting from model 2 that concerns this period cannot determine whether early BA sites exist in the stratigraphy of known sites, the model did identify areas where they might be found based on known patterns and under the assumption that settlers did not depart the valley. Some notable areas that should be surveyed (and dependant on results, excavated) include a ~3.3km^2 area in the southwest of area 1; a ~2.8km^2 area just east of the Vasilikos river in area 3; a ~0.2km^2 area west of the

Koliokremmos cemetery in area 3 of the Ayios Minas River; and a 2.2km^2 area in the central-western portion of area 1 of the Vasilikos valley (Figure 34). Those areas with Late Chalcolithic and middle BA material should be earmarked for invasive investigation to identify early BA components.

ii. *What areas should be considered for future investigation to locate early, and earlier middle BA sites as inferred by recorded sites and AoAP?*

Model 2 was successful in predicting early BA and earlier middle BA AoAP in all areas of the two valleys except for area 2 in the Ayios Minas valley due to the influence of a lack of recorded sites for the area in the training set and the prevalence of an atypically homogeneous soil profile. Areas that were highlighted for future investigation for sites containing potential pre-BA to earlier Middle BA occupation are listed below by area. They are followed by their priority for investigation level (low, medium, and high) and the type of survey recommended (intensive or extensive).

Model 2: Early BA and Earlier Middle BA (Figure 34)

Area 1

- Vasilikos Valley: the westernmost six AoAP (high priority, intensive survey)
- Ayios Minas Valley: both AoAP (high priority, intensive survey)

Area 2

- Vasilikos Valley: central and southern portion of the AoAP (low priority)
- Ayios Minas Valley: the area inclusive and south (~1.5km) of the area subject to preliminary ground survey (high priority, extensive survey)

Area 3

- Vasilikos Valley: the eastern third of the AoAP, particularly its southern extent where it overlaps with workable soils (high priority, intensive survey)
- Ayios Minas Valley: the southern 70% of the strip of AoAP along western bank of river and western AoAP of the pair to the north (high priority, intensive survey)

Area 4

- Vasilikos Valley: southwest portion (c.1.5km^2) of main AoAP (medium priority, extensive survey)
- Vasilikos Valley: sliver of AoAP located along the coast (medium priority, intensive survey)
- Ayios Minas Valley: all four AoAP (high priority, intensive survey)

iii. *What is the wider spatial extent of settlement patterning during the late BA as inferred by recorded sites and AoAP? Does this patterning suggest a more integrated and perhaps hierarchical settlement system was in practice?*

Model 3 was successful in predicting later middle BA and late BA settlement patterning extent in all areas of the two valleys. Areas that should be marked for future investigation are outlined below. They are followed by their priority level (low, medium, and high) and the type of survey recommended (intensive or extensive).

Model 3: Later Middle BA to Late BA (Figure 35)

Area 1

- Vasilikos Valley: portions of the southwestern AoAP that overlap the marginal soils surrounding the fertile pocket (high priority, intensive survey)
- Vasilikos Valley: the two AoAP along the western side of the river (high priority, intensive survey)
- Vasilikos/Ayios Minas Valleys: the area between the easternmost sites of the Vasilikos valley and the area informally surveyed in the Ayios Minas (high priority, extensive survey)
- Vasilikos Valley: areas of overlap in AoAP between early/middle and the late BA (moderate priority, intensive survey)
- Ayios Minas: entire AoAP (high priority, intensive survey initially with possible extensive survey further north)

Area 2

- Vasilikos Valley: the western side of the river corridor AoAP (moderate priority, intensive survey)
- Vasilikos Valley: north of the AoAP within oxbow of river (moderate priority, intensive survey)
- Vasilikos Valley: south of the AoAP, northeast of Kalavassos cluster (high priority, intensive survey)
- Ayios Minas Valley: the area inclusive and south (c.1.5km) of the area subject to preliminary ground survey (high priority, extensive survey)

Area 3

- Vasilikos Valley: the southwestern portion of the AoAP from the site of Kalavassos-*Ayios Dhimitrios* down to the coastline (moderate priority, extensive survey)
- Vasilikos Valley: 3.3km projection from the main AoAP that extends northeast into the Ayios Minas valley (high priority, extensive survey)
- Ayios Minas Valley: large AoAP that extends along a northeast to southwest trajectory that connects with areas 3 and 4 of the Vasilikos valley (high priority, extensive survey)
- Ayios Minas Valley: three small, isolated clusters to the west, north and northeast of the larger AoAP (high (western AoAP) and moderate (north and northeastern AoAP), intensive survey)

Area 4

- Vasilikos Valley: the AoAP found between present-day Mari village and the Vasilikos river (moderate priority, extensive survey)
- Vasilikos Valley: the coastal AoAP west of Tochni-*Lakkia* (moderate priority, intensive survey)
- Vasilikos Valley: area (c.1.0km^2) surrounding long-lived sites within the late BA AoAP (i.e., Mari-*Mesovouni*)
- Ayios Minas Valley: the 1.5km^2 area in the southwestern portion of the Ayios Minas valley adjacent the west riverbank on the coast (moderate priority, intensive survey)

iv. In what areas might sites that "bridge" or "link" the settlements of the valleys, particularly the large "primary" centers of the lowlands in the late BA be located?

There is uncertainty surrounding the extent and nature of interaction between the settlements of the two valleys over the course of the BA. This uncertainty could be extended back into the early BA but is more commonly applied to the later middle and late BA during the period in which it is presumed that valley settlement systems were centred on the primary "mega sites" such as Kalavassos-*Ayios Dhimitrios* located in the northern lowlands of the Vasilikos Valley. Specifically, it is uncertain whether the Maroni Complex located in the southern lowlands of the Ayios Minas valley was an independent entity functioning much like *Ayios Dhimitrios* within the context of its own valley or whether it occupied a tier within the wider hierarchy centred on the Vasilikos valley.

The resolution of the results of the predictive models is at the inter-settlement level and cannot answer questions about the internal nature of settlements except by inferring such characteristics from excavated sites that share aspects of their geochemistry, geomorphology, etc. Addressing questions about communication and contact will come from analysing diachronic changes to AoAP identified in key areas over the course of the BA, particularly how they ebb and flow and whether this might suggest interaction and perhaps co-operation. Of note are settlements and AoAP between the valleys, but particularly those situated at the eastern fringe of the Vasilikos (closer to the Ayios Minas valley) far outside of the otherwise north-to-south oriented settlement patterning. It is in the areas outlined below that survey where subsequent higher resolution investigation through remote sensing and excavation would be ideal.

<u>Area 1</u>
Area 1 contains settlements established for copper mining and beneficiation, particularly in the central and northern portion but probably also subsistence surplus production in the southwest around the pocket of fertile soil. Most sites and AoAP in this area are close to the Vasilikos river, however the two Ora sites are in the far east on the marginal chalk plateau soils. The proximity to known late BA sites in the Ayios Minas midlands (1.8km) and distance from fertile soil and copper in the Vasilikos valley suggest that they may have been established to interface with settlements of the neighbouring valley and perhaps serve as a departure point for raw copper moving that direction. It is recommended that particular care be made in this area when surveying and that survey extend from the informally surveyed area in the Ayios Minas valley up to the eastern portion of area 1 in the Vasilikos valley (Figure 38).

<u>Area 2</u>
Settlements tend to cluster tightly on the banks of the Vasilikos river throughout area 2, presumably due to its fertile soils in what is otherwise an area dominated by marginal chalky erodible earth. By contrast, the pair of *Oriti* sites that are established well away from the river out toward the Ayios Minas valley are intriguing. It is in the area between the *Oriti* settlements and the more promising AoAP in the Ayios Minas valley (see recommended areas of potential survey above) that intervening settlement might exist. The purpose of such sites here would be linked to the transit of goods from the Vasilikos valley including copper and possibly olive oil from *Ayios Dhimitrios* but also subsistence surplus produced in the highly fertile deposit present (this far north) in the Ayios Minas valley. One very promising area for investigation is the AoAP clusters outlined for areas 2 in the Ayios Minas valley, but potential also that which lies in the area east of the Tochni-*Oriti* sites in the AoAP 0.6km east (Figure 38).

<u>Area 3</u>

Throughout the BA, area 3 would have been a nexus for the facilitation of trade, exchange, communication and transport between the coast, lowlands, midlands, and uplands, potentially cross-valley and eventually intra-island and the wider Mediterranean world system. It is in areas 3 and 4 where the potential for inter-valley interaction is probably highest due to the rivers (around which settlement clusters) being much closer together, where fertile soils more abundant, the topography gentler, settlement density being higher and the ports (and potential markets) being the heart of commerce, are situated. The AoAP for area 3 predicted by model 3 consist of an east to west strip that is infilled with recorded sites and an eastern AoAP that runs east and then northeast up into the Ayios Minas valley. This eastern portion contains no known sites, entirely occupies a reasonably fertile soil island (ideal for domestic construction) within a highly fertile sea of soil and was only marginally surveyed, making it a very promising area for investigating inter-valley settlement. The core of this AoAP should be intensively surveyed. Unlike areas 1 and 2 that hold some promise for settlement bridging the valleys it is the opinion of the author that area 3 is where the bulk of interaction would have been undertaken and has the highest chances of producing sites through ground survey that could be more rigorously investigated.

Area 4

The "primary" centres of Kalavassos-*Ayios Dhimitrios* and the Maroni Complex were established in area 4 during the later middle BA and came to comprise the focal point of valley wide socioeconomics. It is probably simplistic to suggest that the Maroni complex is a smaller version of the Kalavassos complex serving the same purpose only in the neighbouring valley. This opinion overlooks the significant differences between the two including the more northerly situation, greater orientation toward production, larger size, and earlier establishment of *Ayios Dhimitrios*. Despite these differences the clusters are both closely associated with the control of inland administrative centres, coastal ports and several inland settlements occupied in extractive and processing activities.

How the two centres interacted is unclear, but as they are reasonably close at <5.0km, it's unlikely they didn't. It is postulated that while Kalavassos-*Ayios Dhimitrios* undertook administrative, production and ceremonial roles, the Maroni Complex undertook commercial functions (Knapp 2013: 357). Beyond the macro-characteristics that are the focus of this study, further excavation is likely to be required in these settlements and intervening sites to better address the nature of their distinctions and to what extent this emerging relationship was hierarchical or heterarchical. The suggestions below may provide targets for this higher resolution investigation.

At first glance much of the AoAP in area 4 occupies the intervening space between the valley complexes. Unfortunately, most of this area is occupied by known settlements or highly fertile soils which were rarely occupied in the BA due to the tendency to settle on marginal soils. One notable area is the region of overlap of the eastern portion of the Vasilikos AoAP and southwestern portion of the Ayios Minas AoAP. This region contains a suitable soil profile for subsistence surplus production, is close to the Maroni complex and its port, could access coastal resources with ease and is close (within 1.2km) to Vasilikos settlements.

v. In what areas might early evidence for local development of the tiered system be found?

There are several areas of evidence that suggest the hierarchical settlement system present in the late BA was a local development with roots in the early to earlier middle BA. While many settlements were abandoned in the earlier middle BA there is evidence that many others drifted, relocated to a new location or integrated with nearby emerging settlements. This makes the identifying succession of settlements murky but perhaps the clearest examples of local development are the early and earlier middle BA origins of some of the larger settlements of the later tiered system.

Most notable are *Spilios* in the northeast of the Vasilikos valley and *Mitsingitis, Lourca, alonia tou pano zyou, Laroumena, Arkhangelos, Khorapheri/Vounaritashi* in the south-central lowlands and along the coast and the *Oriti* sites and *Perivolia* in the eastern lowlands. Each of these sites or "mega sites"/complexes developed an economic focus on goods and/or services that contributed to their success in the later middle BA and late BA socioeconomics. *Laroumena* in subsistence surplus production, copper working and textiles; *Khorapheri/Vounaritashi* in subsistence surplus, copper, and ceramics; the *Oriti* sites and *Perivolia* in subsistence surplus and copper smelting. In some cases, the settlements remained in place and in others they shifted slightly or had to relocate in response to changing circumstances such as *Oriti* to *Perivolia*

While outside of the study area, the prominent industrial ceramic production of *Sanidha Moutti tou Ayious Serkou* that supplied much of the pottery consumed by the Vasilikos valley (including Kalavassos-*Ayios Dhimitrios)* possesses an early BA component. The important takeaway from this list is that the Vasilikos valley possessed the metal and mineral deposits, fertile soils and other raw materials that underpinned the late BA economy (Knapp 2013: 353). Keswani (1996; 2004: 154-156) took this to support a locally developed settlement system (at least in the Vasilikos valley) rather than a foreign transplant that is argued for in other parts of the island. More evidence is required to make this case for the Ayios Minas valley as it remains unclear as to whether it was extracting and processing its own copper for consumption and export, was either a later extension of the Vasilikos system, or was dependant upon it.

There are a few key AoAP that can help understand how to view this dynamic. These include:

<u>Area 1</u>
Tracking the use life of copper from local prestige material to finished product and perhaps intra or inter island trade commodity is important for understanding the degree to which powerful sites exercised influence. An ideal location to begin is close to the source of the copper itself and sufficient far back enough in the BA to identify why copper became a commodity. Unfortunately, none of the earliest known sites in this area are sufficiently close enough in proximity to definitively claim that they are the predecessors of late BA sites. The most likely location for predecessor sites in area 1 would be in the model 2 AoAP northwest of the three earlier middle BA Ora sites and the AoAP northeast and northwest of the early BA Asgata sites. The Asgata sites are particularly promising as they may have an extremely lengthy occupation from late Chalcolithic through into the Iron Age providing a cross-section of copper exploitation through the entire BA.

<u>Area 2</u>
Area 2 is a large area that is thought to have contained settlements belonging to the secondary and tertiary tiers in the late BA settlement system. The roles of such settlements were probably linked to their position along the river such that those further north would have probably assisted in the transport and administration of copper from the mines while those further south were positioned between the large fertile soil deposits of the inter-valley region and the Kalavassos cluster and were then were instrumental in subsistence surplus transport, administration, and processing. The settlements in the middle of the area were also dependent on location for their roles. Those on the west side of the river were placed to farm the cluster of fertile soils while those on the east are less clearly understood but may have functioned to facilitate the movement of goods between the two valleys. While all later middle to late BA settlements resides close to or superimpose predecessor sites, there are few areas that reside in AoAP that lack recorded predecessor sites. The portions of the

AoAP most appealing for investigation include northwest area north of Kalavassos-*Gouppos* and perhaps the southern extent of the AoAP north of Kalavassos-*Mitsingitis* which may produce early sites linked to copper and subsistence surplus transport respectively.

Area 3

Later middle and late BA sites in area 3 can be split into those forming the north and eastern portion of the Kalavassos cluster and those occupying the margins of the inter-valley fertile soils. There are important predecessor sites are found in the Kalavassos cluster, though most comprising it at its greatest extent were newly established in the later middle BA. It is hypothesised that the Kalavassos cluster may have been responsible for the production and administration of many of the goods distributed throughout the valleys and marked for export, perhaps via the Maroni complex and the port site of Tochni-*Lakkia*. Some areas that might be investigated for predecessor sites include the eastern extent of the AoAP where early settlements extending out to the Ayios minas might be recorded.

Area 4

Recorded settlement is that spans the entire BA is bias toward the central and eastern portion of the Vasilikos lowlands. Few predecessor sites exist in the lowlands proper due to the difficulty in cultivating these fertile soils in these earlier periods but also as they may be buried under alluvial/colluvial deposits. Any early sites in this area are largely confined to the looser fertile river soils and marginal pockets. Those that occupied the marginal pockets that happened to be close to the fertile soils were well positioned when the requisite technology and economic incentives arrived. These sites include *Kafkalia A, Pamboules and Ayious* that all unsurprisingly reside close to later sites of the tiered settlement system. Two AoAP stand out for potentially containing predecessor sites. The first is the sliver along the coast that runs through the late BA port site of Tochni-*Lakkia* that may contain evidence for its early formation. Investigation should focus to the west and offshore. The second is the southwestern portion of the lowlands that contain no recorded later middle BA nor late BA sites but may contain earlier sites that shifted east when the fertile soils could be more effectively cultivated.

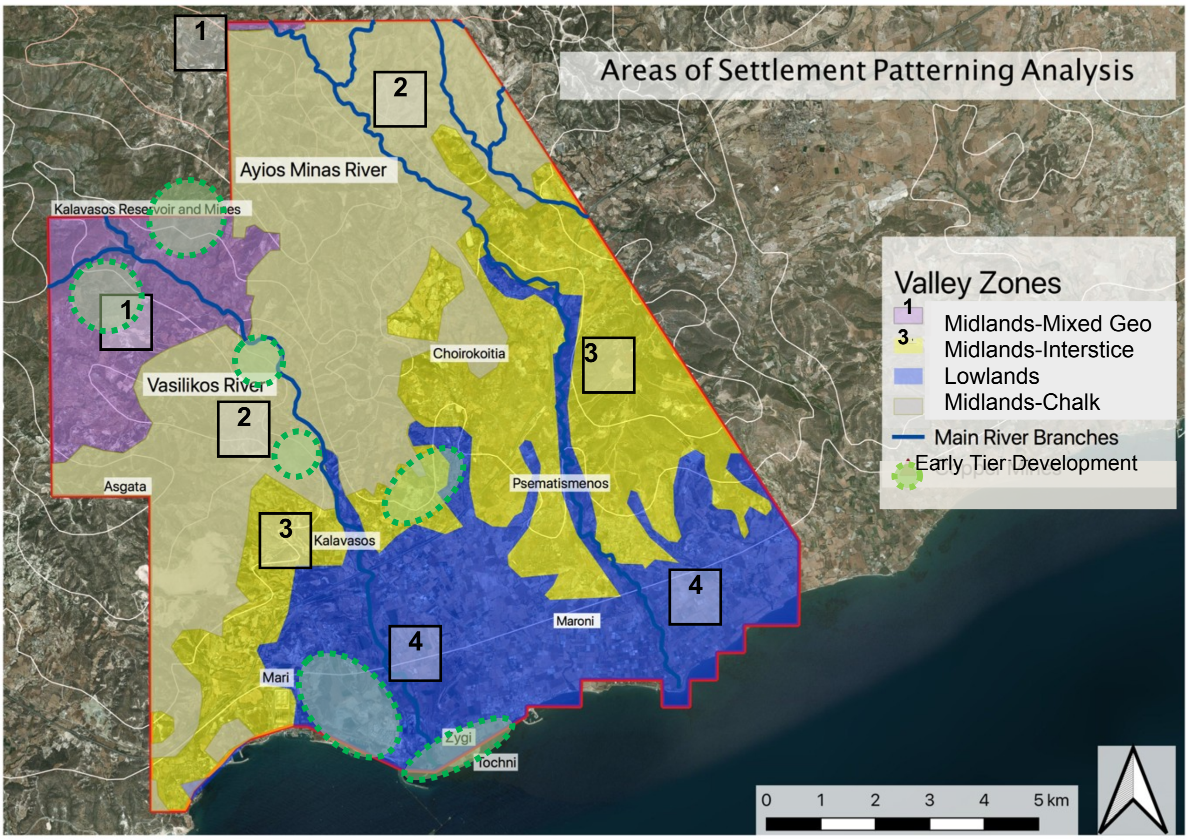


Figure 38: This map depicts the four areas (per valley) used to frame discussion on diachronic settlement patterning and socioeconomic evolution in the Vasilikos and Ayios Minas River valleys during the Bronze Age. Areas to investigate that may contain sites indicative of the early development of the tiered settlement system are indicated by dashed rings. Base map from Google Earth, https://earth.google.com/web/

8.4 Aim 4: Additional Future Work

In addition to the many surveys and interventions that are recommended above, there are several small desk-based projects that could follow this study. The first is incorporating the results of the informal survey into the training data of the three models to improve the representation of AoAP in the Ayios Minas midlands. A second project would be to extend the northern study area boundary to encompass much more of the Ayios Minas upper midlands geology as there are undoubtedly more AoAP to analyse that would help clarify where to look for sites that link the Ayios Minas valley to copper exploitation. In line with the second project, would be predictive modelling that includes the uplands of the valleys to capture diachronic settlement patterning throughout the entirety of both valleys. There are several observations from model 1 and the informal survey that can generate informative and robust field projects including excavation of a probable BA cemetery, survey of a long-lived terrace system and a higher resolution and standardised ground survey of the Ayios Minas middle valley.

8.5 Conclusions

The WoE method proved an effective tool for evaluating BA archaeological sites against the occurrence of several attributes of the natural and anthropogenic environment in the Vasilikos and Ayios Minas valleys of the south-central coast of Cyprus. Weights based on the pattern of those attributes and the occurrence of archaeological sites were generated and combined to produce a probability surface of areas of archaeological potential for three chronological contexts. The resulting predictor maps demonstrated the theoretical spatial layout and maximum extent of settlement patterning on either side of a pivotal shift in BA socioeconomics as well as for a third model that assigns AoAP regardless of chronological context for practical guidance in modern landuse policy. WoE also proved effective in addressing various sources of bias and uncertainty inherent in predictive models in general and in the raw data of this study to the degree that would otherwise be difficult and corrupt results. The three models addressed the aims of the study insofar as they provided AoAP that identify patterns to be interpreted within existing theory and models and further suggested areas that may address the finer point of these questions through invasive and non-invasive investigation.

The WoE method provided a rich environment for identifying relationships between geology and socioeconomic behavior that should be further explored in the study area and throughout the island proper in the context of existing theories. The main topics addressed include whether survey data from diverse spatial loci and chronological foci can be combined using the WoE method in a way that offsets the effects of these biases; how soil and geology influenced settlement patterning and socioeconomics throughout the BA; how the natural resources of the valley coupled with developing prestige markets throughout the region shaped socioeconomics in the study area; whether settlement patterning (both recorded and predicted) align with the theory and models put forth; where the enigmatic early BA settlements might exist; in which areas might predecessors to the later middle BA and late BA sites of the settlement hierarchy be found; where might unrecorded sites of the early BA/earlier middle BA be located; where might unrecorded sites of the later middle BA/late BA be located; in which areas might sites that “bridge” the two valleys be found; how could such sites clarify the nature of inter-valley relations over time (including between the Kalavassos and Maroni complexes); and in which areas might sites that contain information about post-late BA settlement be found.

These predictions provide guidance for current theory and future investigations into the socioeconomics and settlement patterning of the Bronze Age Vasilikos and Ayios Minas River valleys. These models have created several important areas of further enquiry that could constitute future studies including large scale ground/aerial surveys of the previously unsurveyed Ayios Minas midlands to clarify the nature and extent of settlement, intensive survey of the upper midland/upland interstice of the Vasilikos valley to improve understanding of diachronic copper exploitation and intensive survey of the inter-valley interstice to elucidate inter-valley interaction over time among many others.

The diachronic spatial patterning of settlement and subsistence exploitation of the valleys may best be understood as a product of changing relationships of farmers to chemical and mechanical soil properties through the medium of technological innovation, demographic pressures, socioeconomic development, and political change. With good background knowledge of this interplay, the WoE method can both predict how settlement expanded, contracted, and shifted in anticipation and response to these factors in a verifiable and testable process that improves our understanding of the interplay between socioeconomic development and settlement patterning in BA Cyprus.

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APPENDIX A

TABLE A: TRAINING THEME RAW DATA SET

Data Layer	Format	Acquired From	Notes
VVP Sites (Points)	Analog, digitized to Shapefile (point)	Digitized from analog records in Todd I. (2004; 2013).	120 sites identified during the VVP survey and attributed to various chronological periods and spatial extents with emphasis on the Bronze Age.
MVASP Sites (polygons)	Shapefile (polygon)	Andreou, G.M. (2016), MVASP Project associate.	Polygons boundaries demarcate the transition from site to non-site. The density at which this occurs was determined by the project director and field surveyors.
MVASP Sites (Points)	Shapefile (point)	Converted to point data from polygon by Aspland L. in ArcGIS.	24 sites identified during the MVASP survey and attributed largely to the Bronze Age.
All Sites	Shapefile (point)	VVP Sites (points) and MVASP Sites (points) merged by Aspland L. in ArcGIS.	144 total sites indicated by points within AOI.
BA Sites	Shapefile (point)	All Sites shape file	Selection by Attribute and export as separate shape file to produce a point layer containing BA sites only.
training sites_ALL_Periods	Shapefile (point)	'Subset Features' tool used by Aspland, L. to create a training set for predictive survey of 50 sites from ALL chronological periods.	WoE tool, 'training sites reduction' failed to execute. Manual check of subset was made to ensure only one training point per cell was maintained.

training sites_BA	Shapefile (point)	'Subset Features' tool used by Aspland, L. to create a training set for predictive survey of 50 BA sites.	

TABLE B: EVIDENTIAL THEMES RAW DATA SET

Data Layer	Format	Acquired from	Notes
Digital Elevation Model for Southeast Cyprus	Raster	ASTER-GDEM2	The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) is concurrently distributed from the Ministry of Economy, Trade, and Industry (METI) Earth Remote Sensing Data Analysis Center (ERSDAC) in Japan and the National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) Data Information System (EOSDIS) Land Processes (LP) Distributed Active Archive Center (DAAC) in the United States. Version 2 is produced with the same gridding and tile structure as Version 1. Improvements over version 1 include the use of additional scenes to improve coverage, a smaller correlation kernel to yield higher spatial resolution, and an improved water mask. Spatial resolution of 1 arc-second (approximately 30 meters).
Slope	Raster	Created by the author in ArcGIS.	Slope create using (Raster>Terrain Analysis>Slope). Converted from Floating point to Integer using Int

			(Spatial Analyst) after rounding in raster calculator “Int(G1 + 0.5)” for WoE modeling.
Geology 250k	Shapefile	Department of Lands and Surveys- Government of Cyprus	Original analog map scale is 1:250,000.
Geology 250k	Raster	Converted to raster data from polygon by Aspland L. in ArcGIS.	Converted from Floating point to Integer using Int (Spatial Analyst) after rounding in raster calculator “Int(G1 + 0.5)” for WoE modeling.
Hydrogeology250k	Shapefile	Department of Lands and Surveys- Government of Cyprus	Original analog map scale is 1:250,000.
Hydrogeology250k	Raster	Converted to raster data from polygon by Aspland L. in ArcGIS.	Converted from Floating point to Integer using Int (Spatial Analyst) after rounding in raster calculator “Int(G1 + 0.5)” for WoE modeling. Original analog map scale is 1:250,000.
Vegetation	Shapefile	Department of Lands and Surveys- Government of Cyprus	Original analog map scale is 1:250,000.
Vegetation	Raster	Converted to raster data from	Converted from Floating point to

		polygon by Aspland L. in ArcGIS.	Integer using Int (Spatial Analyst) after rounding in raster calculator "Int(G1 + 0.5)" for WoE modeling. Original analog map scale is 1:250,000.
LandUseCORINE2006	Shapefile	Department of Lands and Surveys-Government of Cyprus	The scale of all output products of CLC is set to 1:100000, facilitating the detection of essential features of the terrain by means of satellite images (Spot, Landsat MSS, TM and IRS) and their representation.
LandUseCORINE2006	Raster	Converted to raster data from polygon by Aspland L. in ArcGIS.	The Corine Land Cover 2012 (CLC 2012) project in Ireland forms part of the update of land cover maps for the whole of Europe and is coordinated by the European Environment Agency. Ireland previously participated in the Corine 1990 land cover mapping project, and the Corine 2000 and 2006 was managed by the Environmental Protection Agency (EPA) in Ireland. The 2006 project was developed for the EPA by ERA-Maptec under the supervision of a Steering Committee. The 2012 dataset is being produced 'in-house' by land cover and remote sensing experts within the EPA. The Corine Land Cover inventory is based on satellite images as the primary information source. The use of earth observation data has

			important implications on the nomenclature, mapping unit and scale. For the 2012 data series additional GIS vector land cover datasets will be used to aid the classification process. Converted from Floating point to Integer using Int (Spatial Analyst) after rounding in raster calculator "Int(G1 + 0.5)" for WoE modeling. The scale of all output products of CLC is set to 1:100000, facilitating the detection of essential features of the terrain by means of satellite images (Spot, Landsat MSS, TM and IRS) and their representation.
Soils250k1998	Shapefile	Department of Lands and Surveys-Government of Cyprus	Original analog map scale is 1:250,000.
Soils250k1998	Raster	Converted to raster data from polygon by Aspland L. in ArcGIS.	Converted from Floating point to Integer using Int (Spatial Analyst) after rounding in raster calculator "Int(G1 + 0.5)" for WoE modeling. Original analog map scale is 1:250,000.
Rivers 100k	Shapefile	Department of Lands and Surveys-Government of Cyprus	Original analog map scale is 1:100,000.
Rivers 100k Buffer	Shapefile	Created by Aspland L. in ArcGIS.	1km buffer around rivers suggesting a roughly ~30min walk from settlement due to rugged and steep

			terrain to flowing fresh water. Original analog map scale is 1:100,000.
Rivers 100k Buffer	Raster	Converted to raster data from polygon by Aspland L. in ArcGIS.	Converted from Floating point to Integer using Int (Spatial Analyst) after rounding in raster calculator "Int(G1 + 0.5)" for WoE modeling. Original analog map scale is 1:100,000.

TABLE C: BOUNDARY THEME DATA SET

Data Layer	Format	Acquired from	Notes
Vasilikos Valley Survey Boundary	Analog, converted to Shapefile	Digitized from analog records in Todd I. (2004; 2013) by Aspland, L.	
Ayios Minas Lower Valley (MVASP) Survey Boundary	Shapefile	Andreou, G.M. (2016), MVASP Project associate.	
Ayios Minas Middle Valley	Shapefile	Digitized by Aspland L. in ArcGIS.	
All boundaries	Shapefile	VVP, MVASP and AMMV Boundary merged by Aspland L. in ArcGIS.	
All boundaries	Raster	Converted to raster data from polygon by Aspland L. in ArcGIS.	

TABLE D: SITES OF THE VASILIKOS VALLEY (those randomly selected as training sites for the ALL chronological period model are indicated with a darker background).

VASILIKOS VALLEY		
Site Name	**Period(s)**	**Site Type**
Agata-Kambos	MC/LC/MBA/Ar/H/R/LR/M	Site/Tomb
Asgata-Ayia Marina	MBA/LBA/Ar/R/LR/M	Site
Asgata-Neron tou Phani	LChal/MBA/Ar/LR	Site
Kalavasos Kafkalia I-II	Ceramic Neolithic/MBA	Site
Kalavasos-Alonia tou Pano Zyou	LChal/MBA/LBA/Ar/R/LR	Site

VASILIKOS VALLEY		
Site Name	**Period(s)**	**Site Type**
Kalavasos-Ammos	MBA/LBA/Ar	Site/Tomb
Kalavasos-Andronikidhes	MBA/LBA/Ar/R	Site

Kalavasos-Angastromeni	Ceramic Neolithic/MBA	Site
Kalavasos-Argaki	MBA/LBA/Ar/H/R	Site
Kalavasos-Argaki East	CN/MBA/Ar/M	Site
Kalavasos-Argaki tou Tahiri	MBA/LBA	Site
Kalavasos-Argaki tou Yeoryiou	Late Chalcolithic/MBA/LR	Site
Kalavasos-Arkhangelos	MC/LC/MBA/LBA/Ar/R/LR	Site
Kalavasos-Ayiasmata	MBA/LBA/Ar/R	Site
Kalavasos-Ayios Dhimitrios	MBA/LBA/Ar/R/LR	Site/Tomb
Kalavasos-Ayios East	MBA/LBA/Ar/R/LR	Site
Kalavasos-Ayios Kaloyeros	MBA/Ar/R/LR/M	Site
Kalavasos-Ayios Yeoryios Kephala	CN/Ar	Site/Tomb
Kalavasos-Ayious	EC/MBA/Ar/R/LR	Site/Tomb
Kalavasos-Bamboules	MBA	Site

Kalavasos-Draconikiaes	MBA/LBA/Ar/LR	Site
Kalavasos-Fournia	MBA/Ar	Site
Kalavasos-Gouppos	MBA/LBA/Ar/R/LR	Site
Kalavasos-Ipsopamboulos	LChal/MBA	Site
Kalavasos-Kafkalia III	MBA/Ar	Site/Tomb
Kalavasos-Kafkalia IV	MBA/LBA/Ar/R/M	Site
Kalavasos-Kafkalia V	AN/MBA/LBA/Ar/LR	Site
Kalavasos-Kafkalia VI	Early Chalcolithic/MBA	Site
Kalavasos-Kafkalies	Ar/Cl	Tomb
Kalavasos-Kaoukkos	MBA/LR/M	Site
Kalavasos-Kaparovouno	MBA/LBA/Ar/H/R	Site
Kalavasos-Kaphkalia A	CN/Chal/MBA/H/M	Site
Kalavasos-Kaphkalia B	MBA/LBA/Ar/Cl/R/LR/M	Site
Kalavasos-Kaphkalia C	MBA/Ar/M	Site
Kalavasos-Kharkokolymbos	MBA/LBA/Ar/H/R/LR	Site
Kalavasos-Khorapheri/Vounaritashi	MBA/LBA/Ar/H/R/LR	Site
Kalavasos-Kokkino Kremmos	MBA/LBA/Ar/R/LR	Site
Kalavasos-Kokkinoyia	CN/MBA/LBA/Ar/R/LR/M	Site
Kalavasos-Kondon Klisourin	MBA/LBA/Ar	Site
Kalavasos-Kopetra	LBA/LR	Site
Kalavasos-Krommidhia	MBA/Ar	Site/Tomb
Kalavasos-Laroumena	CN/MBA/LBA/Ar/R	Site/Tomb
Kalavasos-Latomari/Argakia	MBA/LBA/Ar/R/LR	Site
Kalavasos-Loas/Pamboules	R/LR	Site

Kalavasos-Lourca	MBA/LBA/Ar/M	Site/Tomb
Kalavasos-Lourca North	Ar	
Kalavasos-Mandres tou Sani	Ar	Site
Kalavasos-Mangia III	MBA/LBA/Geo/Ar/LR	Site
Kalavasos-Mangia Tombs 7 and 8	LBA	Tomb
Kalavasos-Markotis	CN/MBA/LBA/Ar/R/M	Site
Kalavasos-Mazeri	CN/MBA/LBA/Ar/R/LR	Site
Kalavasos-Melisotriba	MBA/R/LR	Site
Kalavasos-Melisotriba East	Late Chalcolithic/MBA/Ar	Site
Kalavasos-Mitsingites	CN/MBA/LBA/Geo/Ar/H/R/LR/M	Site/Tomb
Kalavasos-Pamboules	EC/MChal/LChal/MBA/LBA/Ar/R/LR/M	Site
Kalavasos-Pamboules tou Haji Mikhaili	CN	Site
Kalavasos-Perivolia I	MBA/M	Site
Kalavasos-Perivolia II	MBA/Ar/LR	Site
Kalavasos-Pervolia	MBA/LBA/Ar/R	Site
Kalavasos-Petra I	Ar/H	Tomb
Kalavasos-Petra II	LBA/Ar/Cl/H/R	Site

Kalavasos-Pidieri	MBA/LBA/Ar/R	Site/Tomb
Kalavasos-Plakes	Cl/R	Tomb
Kalavasos-Potamia	MBA/Ar/R/LR	Site
Kalavasos-Potima I, II, III	LChal/MBA/LBA/Ar/R/LR/M	Site
Kalavasos-Psoumadhes	MBA/LBA/Ar	Site
Kalavasos-Sirmata	CN/MBA/LBA/Ar/LR	Site/Tomb
Kalavasos-Skhisti Petri	MBA/LBA	Site
Kalavasos-Sokopra	AN/LBA/Ar/LR	Site
Kalavasos-Spilios	CN/MBA/Ar/R/LR/M	Site/Tomb
Kalavasos-Tenta	AN/EChal/MBA/LBA/Ar/R/LR/M	Site
Kalavasos-Vasilikos River Bridge Site	AN/Ceramic Neolithic/Chalcolithic/MBA	Site
Kalavasos-Village-Cinema Area	MBA	Tomb
Kalavasos-Village-Mosque/ Mavrovouni Area	MBA/LBA	Tomb
Kalavasos-Village-Panayia Church Area	MBA/LBA	Tomb
Kalavasos-Village-Plot 37	LBA	Site
Kalavasos-Yeromano	CN/MBA/LNA/Ar/H/R	Site
Kalavasos-Yirtomylos	CN/LC/MBA/Ar/H/R/LR	Site/Tomb

Kalavasos-Zoulfdidhes	CN/MBA/LBA/Ar/R/LR	Site
Kalvasos-Loures	MBA	Site
Mari-Alonotopo	Ar/M	Tomb
Mari-Asprous	R	Site
Mari-Kalotsikous	MBA/Ar/R	Site
Mari-Kopetra	H/R	Site
Mari-Koupetra-Loura-Kaphkaloudi	R/M	Site
Mari-Kremmos tou sani/Livadhia	MBA/Ar	Site
Mari-Matsounin/Mandra tou Rirou	CN/MBA/LBA/Geo/Ar/R/LR/M	Site/Tomb
Mari-Mazera	Ar	Tomb
Mari-Mesovouni	AN/LC/MBA/LBA/Ar/H/R/LR	Site
Mari-Paliembela	CN/MBA/LBA/Ar/H/R/M	Site/Tomb
Mari-Skali I	CN/MBA/LBA	Site
Mari-Skali II	MBA/LBA/Ar	Site
Mari-Village	Ar	Tomb
Ora-Ammouthia	MBA	Site
Ora-Aspro Khorapha	MBA/LBA/Ar/R/LR/M	Site/Tomb
Ora-Betaleyi	MBA/LBA/Ar/H/R/M	Site
Ora-Klitari	AN/MBA/Ar/LR	Site

Ora-Lakxia Constandi	MBA/LBA/Ar/LR	Site
Ora-Loures	MBA/Ar/R/LR	Site
Ora-Mazo Kambos	MBA/LBA/H/LR	Site
Ora-Mersinia	MBA/LBA/Ar/R	Site
Tochni-Styllos	Ar	Tomb
Tokhni-Kapsala	MBA/LBA/Geo/Ar/R	Site
Tokhni-Lakkia	Cl/H	Site
Tokhni-Latomaes	CN/MBA/LBA/Ar/H	Site
Tokhni-Mesovouni	CN/MBA/LBA/Ar/H/R	Site/Tomb
Tokhni-Mouthkia	MBA/Ar	Site/Tomb
Tokhni-Oriti North	MBA/LBA/Ar/R/LR/M	Site
Tokhni-Oriti South	MBA/LBA/Ar/R/LR	Site
Tokhni-Petreli	MBA/Ar/R/LR	Site/Tomb
Tokhni-Petreli North	MBA/R	Site
Tokhni-Zorpas	Ar/R	Site
Vari-Livadhia	LR	Site
Zygi-Petrini	LR	Site

TABLE E: SITES OF THE AYIOS MINAS VALLEY (those randomly selected as training sites for the ALL chronological period model are indicated with a darker background).

AYIOS MINAS (MARONI) LOWER VALLEY			
Site Name	**Alterative Name**	**Period(s)**	**Site Type**
Georgos Tomb	1	EBA MBA	
Koliokremmos	2	EBA MBA	Settlement
KY1	~~3~~	Chal	Settlement
KY2	4	Med	Settlement
Maras	5	EBA MBA	
Maroni Kapsaloudhia	6	MBA LBA	
Maroni Petrera	7	Rom	Church
MP1	~~8~~	Rom	
MP2	9	Chal Med	Settlement
Maroni Tsaroukkas	10	MBA LBA	Settlement
MV1	11	Ar	
Maroni Village	12	EBA MBA	Settlement
Maroni Vouni 1	13	Ar	Settlement
Maroni Vournes	14	LBA	Settlement

Maroni Vrysoudhia	15	MBA LBA	Settlement
Maroni Yialos	16	LBA	Settlement
AnonymoPot Concentration	17	-	
Psematismenos Trelloukas	18	EBA MBA	Settlement
Site 1	19	-	
Site 2	20	-	
Site 3	21	-	
Todd Tomb	22	LBA	Cemetery
Maroni Vouni 2	23	Neo	Settlement
Maroni Aspres	24	MBA LBA	Settlement

APPENDIX B:

TABLE F: CALCULATE WEIGHTS RESULTS for GEOLOGY (ALL PERIODS)

GEOLOGY-Random Sample from Entire Site Data Set (n=50)						
Class I	Area (KM2)	N Points	W+	W-	C	Stud(C)
0	0.5	0	0.0000	0.0000	0.0000	0.0000
Alluvium-Colluvium	26.4	13	0.2255	-0.0685	0.2940	0.9119
Terrace Deposits	0.0	0	0.0000	0.0000	0.0000	0.0000
Apalos-Athalassa Kakkarista	7.0	6	0.7746	-0.0709	0.8455	1.9429
Kalavasos	7.8	8	0.9552	-0.1108	1.0661	2.7635
Pakhna (Koronia Member)	2.7	0	0.0000	0.0000	0.0000	0.0000
Pakhna	23.1	5	-0.5969	0.0951	-0.6919	-1.4678
Lefkara	47.2	14	-0.2802	0.1344	-0.4145	-1.3161
Moni	0.7	0	0.0000	0.0000	0.0000	0.0000
Pera Pedi	0.3	1	2.2343	-0.0181	2.2524	2.2297
Lower Pillow Lavas	2.1	0	0.0000	0.0000	0.0000	0.0000
Basal Group	0.5	0	0.0000	0.0000	0.0000	0.0000
Sheeted Dykes (Diabase)	0.6	0	0.0000	0.0000	0.0000	0.0000
Gabbro	1.9	0	0.0000	0.0000	0.0000	0.0000
Dunite	0.0	0	0.0000	0.0000	0.0000	0.0000
Serpentinite	0.0	0	0.0000	0.0000	0.0000	0.0000
Pillow Breccia	0.2	0	0.0000	0.0000	0.0000	0.0000
Polymict Breccia	0.4	0	0.0000	0.0000	0.0000	0.0000
Pillow Lava	4.8	3	0.4631	-0.0234	0.4865	0.8170
Vitrophyric Pillow Lavas	1.0	0	0.0000	0.0000	0.0000	0.0000

TABLE G: CALCULATE WEIGHTS RESULTS for HYDROGEOLOGY (ALL PERIODS)

HYDROGEOLOGY-Random Sample from Entire Site Data Set (n=50)						
Class	Area (KM2)	N Points	W+	W-	C	Stud(C)
1 Clay, marl and siltstone (mainly rocks of the Mesaoria group locally including marl, silt and clay of the Allyvium)	6.1	3	0.2217	-0.0126	0.2343	0.3935
2 Ground water in highly retentive rocks such as chalk interbedded with marls (Pakhna and Lapatza formations)	6.2	8	1.1833	-0.1241	1.3074	3.3891
3 Heavily fractured intrusive rocks	1.1	0	0.0000	0.0000	0.0000	0.0000
4 Mamonia complex including serpentinite	0.2	0	0.0000	0.0000	0.0000	0.0000

5 Plutonic rocks, springs common	2.2	0	0.0000	0.0000	0.0000	0.0000
6 Unconfined ground water in aquifers of secondary importance of mainly massive, highly retentive chalk, occassionally mineralised	49.1	13	-0.3947	0.1864	-0.5810	-1.8021
7 Unconfined ground water in gypsum aquifers, saline in deep confined aquifers	6.0	6	0.9376	-0.0797	1.0173	2.3376
8 Unconfined water in reef limestone and detrital limestone (Koronia and Terra limestone), saline in coastal areas	1.4	0	0.0000	0.0000	0.0000	0.0000
9 Unconfined ground water in sandy parts of Middle Miocene (Pakhna formation)	25.7	1	-2.3117	0.2052	-2.5170	-2.4917
10 Unconfined water generally at shallow depth in connection with riverbeds, deltaic gravel-sand deposits and including estuarine deposits.	19.1	15	0.6935	-0.1942	0.8877	2.8765
11 Volcanics with dominantly submarine pillow lavas, occasional pockets of highly saline water	9.8	4	0.0420	-0.0036	0.0455	0.0874

TABLE H: CALCULATE WEIGHTS RESULTS for VEGETATION (ALL PERIODS)

VEGETATION-Random Sample from Entire Site Data Set (n=50)						
Class	Area (KM2)	N Points	W+	W-	C	Stud(C)
0	1.2	1	0.7748	-0.0109	0.7858	0.7779
1 Built-up area	1.5	1	0.5395	-0.0085	0.5480	0.5425
2 Citrus	3.5	6	1.4732	-0.0999	1.5732	3.6148

3 Dams and Lakes	1.3	0	0.0000	0.0000	0.0000	0.0000
4 Decidious-Vegetables	1.2	0	0.0000	0.0000	0.0000	0.0000
5 Degraded Land	1.7	3	1.4978	-0.0484	1.5462	2.5965
6 Garique	1.0	0	0.0000	0.0000	0.0000	0.0000
7 High Forest	3.9	1	-0.4202	0.0107	-0.4309	-0.4266
8 High Forest and Other	0.9	0	0.0000	0.0000	0.0000	0.0000
9 Maquies	46.8	15	-0.2041	0.1021	-0.3061	-0.9920
10 Maquies and Other	0.5	0	0.0000	0.0000	0.0000	0.0000
11 Olive and Carob Trees	58.0	20	-0.1291	0.0964	-0.2255	-0.7813
12 Vegetables	5.7	3	0.2941	-0.0161	0.3102	0.5209
14 Vine Yards	0.2	0	0.0000	0.0000	0.0000	0.0000

TABLE I: CALCULATE WEIGHTS RESULTS for LANDUSE (ALL PERIODS)

LANDUSE-Random Sample from Entire Site Data Set (n=50)						
Class	Area (KM2)	N Points	W+	W-	C	Stud(C)
0 Salt Water	0.9	2	1.7012	-0.0335	1.7347	2.4036
1 Artificial Surfaces	10.6	4	-0.0422	0.0038	-0.0459	-0.0881
2 Agricultural Areas	61.5	30	0.2175	-0.2572	0.4747	1.6443
3 Forest/Semi-natural Areas	53.5	14	-0.4054	0.2162	-0.6216	-1.9734
5 Freshwater bodies	0.8	0	0.0000	0.0000	0.0000	0.0000

TABLE J: CALCULATE WEIGHTS RESULTS for RIVERS (ALL PERIODS)

RIVER BUFFER-Random Sample from Entire Site Data Set (n=50)						
Class	Area (KM2)	N Points	W+	W-	C	Stud(C)
1 Outwith Buffer	39.3	9	-0.5422	0.1767	-0.7189	-1.9485
2 Within Buffer	85.2	40	0.1767	-0.5422	0.7189	1.9485

TABLE K: CALCULATE WEIGHTS RESULTS for SLOPE (ALL PERIODS)

SLOPE-Random Sample from Entire Site Data Set (n=50)						
Class	Area (KM2)	N Points	W+	W-	C	Stud(C)
0	1.7	2	1.0831	-0.0272	1.1102	1.5384
SLOPE-Random Sample from Entire Site Data Set (n=50)						

Class	Area (KM2)	N Points	W+	W-	C	Stud(C)
1	7.9	2	-0.4379	0.0232	-0.4611	-0.6389
2	9.6	4	0.0549	-0.0046	0.0595	0.1142
3	10.3	6	0.3975	-0.0438	0.4413	1.0140
4	9.1	4	0.1071	-0.0088	0.1159	0.2224
5	8.0	3	-0.0435	0.0028	-0.0463	-0.0778
6	7.0	4	0.3779	-0.0270	0.4049	0.7767
7	6.6	7	0.9921	-0.0975	1.0896	2.6733
8	5.9	0	0.0000	0.0000	0.0000	0.0000
9	5.3	1	-0.7291	0.0221	-0.7512	-0.7437
10	5.0	3	0.4243	-0.0218	0.4462	0.7493
11	4.7	1	-0.6121	0.0174	-0.6294	-0.6231
12	4.7	2	0.0968	-0.0038	0.1006	0.1394
13	4.2	0	0.0000	0.0000	0.0000	0.0000
14	3.8	2	0.2797	-0.0101	0.2898	0.4016
15	3.6	3	0.7474	-0.0330	0.7804	1.3105
16	3.4	2	0.3943	-0.0135	0.4078	0.5650
17	3.3	0	0.0000	0.0000	0.0000	0.0000
18	3.0	2	0.5393	-0.0172	0.5565	0.7711
19	2.7	0	0.0000	0.0000	0.0000	0.0000
20	2.5	1	0.0218	-0.0004	0.0222	0.0220
21	2.2	0	0.0000	0.0000	0.0000	0.0000
22	2.0	1	0.2601	-0.0047	0.2648	0.2621

TABLE L: CALCULATE WEIGHTS RESULTS for SOIL (ALL PERIODS)

SOIL-Random Sample from Entire Site Data Set (n=50)						
Class	Area (KM2)	N Points	W+	W-	C	Stud(C)
0	0.8	1	1.1963	-0.0141	1.2104	1.1983
1 Calcaric-CAMBISOLS and calcaric REGOSOLS	20.4	9	0.1159	-0.0237	0.1396	0.3793
2 Calcaric-fluvic CAMBISOLS and vertic CAMBISOLS	4.4	4	0.8322	-0.0480	0.8802	1.6885

3 Calcaric rendzic LEPTOSOLS and calcaric leptic CAMBISOLS	2.7	5	1.5501	-0.0839	1.6340	3.4663
4 Epipetric CALCISOLS and leptic chromic LUVISOLS	4.4	1	-0.5440	0.0149	-0.5588	-0.5532
5 Eutric GAMBISOLS and eutric anthropic REGOSOLS	1.6	0	0.0000	0.0000	0.0000	0.0000
6 Eutric lithic LEPTOSOLS and eutric skeletic REGOSOLS	10.1	4	0.0115	-0.0010	0.0125	0.0240
7 Gypsiric REGOSOLS and leptic GYPSISOLS	7.6	6	0.6976	-0.0662	0.7639	1.7553
8 Lithic LEPTOSOLS and epipetric CALCISOLS	6.0	4	0.5471	-0.0360	0.5831	1.1186
9 Skeletic calcaric REGOSOLS and calcaric lithic LEPTOSOLS	69.4	16	-0.5331	0.4026	-0.9357	-3.0863

TABLE M: CALCULATE WEIGHTS RESULTS for GEOLOGY (EBA/MBA)

CLASS	AREA_SQ_KM	AREA_UNITS	NO POINTS	WPLUS	WMINUS	CONTRAST
0	0.5455	54550	0	0	0	0
1	**26.4369**	**2643690**	**12**	**0.319788062**	**-0.103890373**	**0.423678435**
2	0.0234	2340	0	0	0	0
4	**7.0459**	**704590**	**3**	**0.255808294**	**-0.017213275**	**0.273021569**
6	**7.842**	**784200**	**6**	**0.841910851**	**-0.090619441**	**0.932530293**
7	2.685	268500	0	0	0	0
8	23.1404	2314040	3	-0.933328788	0.126344976	-1.059673764
10	47.2053	4720530	13	-0.179916428	0.092513322	-0.27242975
12	0.6807	68070	0	0	0	0
14	0.2728	27280	0	0	0	0
16	2.0872	208720	0	0	0	0
17	0.5495	54950	0	0	0	0
18	0.6113	61130	0	0	0	0
20	1.8826	188260	0	0	0	0
23	0.0176	1760	0	0	0	0
25	0.005	500	0	0	0	0
26	0.1931	19310	0	0	0	0
28	0.3583	35830	0	0	0	0
29	**4.8103**	**481030**	**5**	**1.148326489**	**-0.088262416**	**1.236588906**

30	1.0045	100450	0	0	0	0	0

TABLE N: CALCULATE WEIGHTS RESULTS for HYDROGEOLOGY (EBA/MBA)

CLASS	AREA_SQ_KM	AREA_UNITS	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	0.3778	37780	0	0	0	0
1	**6.1208**	**612080**	**4**	**0.68377**	**-0.05082**	**0.73459**
2	6.24	624000	3	0.37679	-0.02386	0.40066
3	1.1267	112670	0	0	0	0
4	0.1698	16980	0	0	0	0
5	2.2498	224980	0	0	0	0
6	49.1279	4912790	10	-0.48268	0.21552	-0.6982
7	5.9833	598330	2	0.01334	-0.00066	0.014
8	1.3768	137680	0	0	0	0
9	25.7012	2570120	2	-1.44423	0.17665	-1.62089
10	**19.094**	**1909400**	**15**	**0.86784**	**-0.27937**	**1.14722**
11	**9.7681**	**976810**	**6**	**0.6218**	**-0.07434**	**0.69614**

TABLE O: CALCULATE WEIGHTS RESULTS for VEGETATION (EBA/MBA)

CLASS	AREA_SQ_KM	AREA_UNITS	NO POINTS	WPLUS	WMINUS	CONTRAST
0	1.1735	117350	0	0	0	0
1	**1.4848**	**148480**	**2**	**1.407038484**	**-0.0370613**	**1.444099781**
2	**3.5021**	**350210**	**3**	**0.954415983**	**-0.04622005**	**1.000636038**
3	1.251	125100	0	0	0	0
4	**1.2333**	**123330**	**3**	**1.998101026**	**-0.06437559**	**2.062476612**
5	**1.7085**	**170850**	**1**	**0.573547977**	**-0.01058952**	**0.584137501**
6	1.0028	100280	0	0	0	0
7	3.8768	387680	0	0	0	0
8	**0.9336**	**93360**	**1**	**1.177875825**	**-0.01673882**	**1.19461465**
9	46.849	4684900	8	-0.6583285	0.247424499	-0.905753
10	0.4997	49970	0	0	0	0
11	57.9557	5795570	20	0.045214715	-0.03940231	0.084617023
12	**5.6936**	**569360**	**4**	**0.756116566**	**-0.05434004**	**0.810456603**
13	0.1718	17180	0	0	0	0

TABLE P: CALCULATE WEIGHTS RESULTS for LANDUSE (EBA/MBA)

CLASS	AREA_SQ_KM	AREA_UNITS	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	0.9294	92940	0	0	0	0
1	10.6258	1062580	1	-1.25412615	0.063037843	-1.31716399
2	**61.4656**	**6146560**	**31**	**0.424672495**	**-0.68063735**	**1.105309848**
3	53.477	5347700	10	-0.56750678	0.272737573	-0.84024435
5	0.8384	83840	0	0	0	0

TABLE Q: CALCULATE WEIGHTS RESULTS for RIVERS (EBA/MBA)

CLASS	AREA_SQ_KM	AREA_UNITS	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	63.6122	6361220	36	-0.02788505	12.0822061	-12.1100912

TABLE R: CALCULATE WEIGHTS RESULTS for SLOPE (EBA/MBA)

CLASS	AREA_SQ_KM	AREA_UNITS	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	**1.7219**	**17219**	**1**	**0.564277283**	**-0.01046285**	**0.574740135**
1	7.8804	78804	3	0.141919233	-0.01012615	0.152045379
2	**9.6285**	**96285**	**5**	**0.452409931**	**-0.04800564**	**0.500415571**
3	**10.2529**	**102529**	**4**	**0.166420321**	**-0.01600903**	**0.182429355**
4	**9.1385**	**91385**	**4**	**0.281489413**	**-0.02549754**	**0.306986949**
5	7.9678	79678	3	0.130889059	-0.00939305	0.140282106
6	**6.9708**	**69708**	**6**	**0.957763089**	**-0.09776922**	**1.055532312**
7	**6.6008**	**66008**	**5**	**0.829970348**	**-0.07344357**	**0.903413922**
8	5.9427	59427	2	0.018664798	-0.00092416	0.019588956
9	5.2719	52719	1	-0.55472432	0.018249932	-0.57297425
10	4.9908	49908	1	-0.49992864	0.015946066	-0.51587471
11	4.6898	46898	0	0	0	0
12	**4.6169**	**46169**	**3**	**0.676601323**	**-0.03712223**	**0.713723553**
13	4.2187	42187	0	0	0	0
14	3.8449	38449	1	-0.23907405	0.006608927	-0.24568297
15	3.6132	36132	0	0	0	0
16	**3.4287**	**34287**	**2**	**0.568671871**	**-0.02145435**	**0.59012622**
17	3.3259	33259	0	0	0	0
18	2.966	29660	0	0	0	0
19	2.737	27370	1	0.100821645	-0.00233643	0.103158078
20	2.4881	24881	0	0	0	0
21	2.2393	22393	0	0	0	0
22	1.9605	19605	0	0	0	0
23	1.7619	17619	0	0	0	0
24	1.5166	15166	0	0	0	0
25	1.2429	12429	0	0	0	0
26	1.0198	10198	0	0	0	0
27	0.8022	8022	0	0	0	0
28	0.7097	7097	0	0	0	0
29	0.5411	5411	0	0	0	0
30	0.3965	3965	0	0	0	0
31	0.3388	3388	0	0	0	0
32	0.2445	2445	0	0	0	0
33	0.1854	1854	0	0	0	0
34	0.1367	1367	0	0	0	0
35	0.1068	1068	0	0	0	0
36	0.078	780	0	0	0	0
37	0.055	550	0	0	0	0
38	0.0532	532	0	0	0	0

39	0.0352	352	0	0	0	0
40	0.0224	224	0	0	0	0
41	0.019	190	0	0	0	0
42	0.018	180	0	0	0	0
43	0.0132	132	0	0	0	0
44	0.0098	98	0	0	0	0
45	0.009	90	0	0	0	0
46	0.0185	185	0	0	0	0
47	0.0141	141	0	0	0	0
48	0.014	140	0	0	0	0
49	0.0139	139	0	0	0	0
50	0.0157	157	0	0	0	0
51	0.0151	151	0	0	0	0
52	0.0253	253	0	0	0	0
53	0.0273	273	0	0	0	0
54	0.0261	261	0	0	0	0
55	0.0225	225	0	0	0	0
56	0.0151	151	0	0	0	0
57	0.0098	98	0	0	0	0
58	0.0174	174	0	0	0	0
59	0.0165	165	0	0	0	0
60	0.0208	208	0	0	0	0
61	0.0198	198	0	0	0	0
62	0.024	240	0	0	0	0
63	0.0357	357	0	0	0	0
64	0.0184	184	0	0	0	0
65	0.0264	264	0	0	0	0
66	0.0422	422	0	0	0	0
67	0.0403	403	0	0	0	0
68	0.0343	343	0	0	0	0
69	0.039	390	0	0	0	0
70	0.0523	523	0	0	0	0
71	0.0282	282	0	0	0	0
72	0.0255	255	0	0	0	0
73	0.026	260	0	0	0	0
74	0.0232	232	0	0	0	0
75	0.0375	375	0	0	0	0
76	0.0309	309	0	0	0	0
77	0.0517	517	0	0	0	0
78	0.0691	691	0	0	0	0
79	0.0462	462	0	0	0	0
80	0.0879	879	0	0	0	0
81	0.1114	1114	0	0	0	0
82	0.1263	1263	0	0	0	0
83	0.0677	677	0	0	0	0

TABLE S: CALCULATE WEIGHTS RESULTS for SOIL (EBA/MBA)

AREA_SQ_KM	AREA_UNITS	NO_POINTS	WPLUS	WMINUS	CONTRAST
0.7699	76990	0	0	0	0
20.4125	2041250	5	-0.29754918	0.047963793	-0.345512973
4.4321	**443210**	**4**	**1.00658779**	**-0.064657209**	**1.071244999**
2.7024	**270240**	**7**	**2.060953701**	**-0.160871052**	**2.221824753**
4.3876	438760	1	-0.369622185	0.010966936	-0.380589121
1.6186	161860	0	0	0	0
10.0703	**1007030**	**5**	**0.409010296**	**-0.044365022**	**0.453375318**
7.6059	**760590**	**5**	**0.689678141**	**-0.065162794**	**0.754840935**
5.8942	**589420**	**6**	**1.126958748**	**-0.106756964**	**1.233715712**
69.4427	6944270	9	-0.934118163	0.547066062	-1.481184225

TABLE T: CALCULATE WEIGHTS RESULTS for GEOLOGY (LBA)

CLASS	AREA_SQ_KM	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	0.5455	0	0	0	0
1	**26.4369**	**16**	**0.186256456**	**-0.055100153**	**0.241356608**
2	0.0234	0	0	0	0
4	**7.0459**	**6**	**0.52774454**	**-0.041545524**	**0.569290065**
6	**7.842**	**7**	**0.574847614**	**-0.052300548**	**0.627148162**
7	2.685	0	0	0	0
8	23.1404	5	-0.843717492	0.1191075	-0.962824992
10	47.2053	23	-0.030584643	0.017575863	-0.048160506
12	0.6807	0	0	0	0
14	**0.2728**	**1**	**1.987475453**	**-0.013604796**	**2.00108025**
16	**2.0872**	**3**	**1.05122565**	**-0.03149029**	**1.08271594**
17	0.5495	0	0	0	0
18	0.6113	0	0	0	0
20	**1.8826**	**2**	**0.748926447**	**-0.016861116**	**0.765787563**
23	0.0176	0	0	0	0
25	0.005	0	0	0	0
26	0.1931	0	0	0	0
28	0.3583	0	0	0	0
29	4.8103	0	0	0	0
30	**1.0045**	**1**	**0.683942493**	**-0.007832364**	**0.691774857**

TABLE U: CALCULATE WEIGHTS RESULTS for HYDROGEOLOGY (LBA)

CLASS	AREA_SQ_KM	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	0.3778	0	0	0	0
1	**6.1208**	**4**	**0.262550813**	**-0.015276893**	**0.277827705**
2	**6.24**	**7**	**0.802883908**	**-0.065586573**	**0.868470481**
3	1.1267	0	0	0	0
4	0.1698	0	0	0	0
5	2.2498	1	-0.122894155	0.002077788	-0.124971943
6	49.1279	20	-0.210748034	0.112762203	-0.323510237
7	**5.9833**	**4**	**0.285271515**	**-0.0164106**	**0.301682114**
8	1.3768	0	0	0	0

9	25.7012	2	-1.865447001	0.193695245	-2.059142246
10	**19.094**	**21**	**0.78310201**	**-0.235224497**	**1.018326507**
11	9.7681	5	0.01826378	-0.001532555	0.019796335

TABLE V: CALCULATE WEIGHTS RESULTS for VEGETATION (LBA)

CLASS	AREA_SQ_KM	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	1.1735	0	0	0	0
1	**1.4848**	**2**	**0.985823291**	**-0.020019811**	**1.005843102**
2	**3.5021**	**8**	**1.51404432**	**-0.10564383**	**1.61968815**
3	1.251	0	0	0	0
4	**1.2333**	**2**	**1.171412617**	**-0.022016215**	**1.193428832**
5	**1.7085**	**3**	**1.250956779**	**-0.034501328**	**1.285458107**
6	1.0028	0	0	0	0
7	3.8768	1	-0.667064768	0.015170196	-0.682234964
8	**0.9336**	**1**	**0.756660633**	**-0.008389617**	**0.76505025**
9	46.849	19	-0.214543906	0.106512639	-0.321056544
10	0.4997	0	0	0	0
11	57.9557	25	-0.152856064	0.111904142	-0.264760206
12	**5.6936**	**3**	**0.047217544**	**-0.002265635**	**0.049483179**
13	0.1718	0	0	0	0

TABLE W: CALCULATE WEIGHTS RESULTS for LANDUSE (LBA)

CLASS	AREA_SQ_KM	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	**0.9294**	**1**	**0.761169545**	**-0.008422844**	**0.769592389**
1	10.6258	5	-0.065899665	0.00578957	-0.071689235
2	**61.4656**	**34**	**0.095831111**	**-0.098547552**	**0.194378663**
3	53.477	23	-0.155810415	0.099359763	-0.255170178
5	**0.8384**	**1**	**0.864214616**	**-0.009142487**	**0.873357103**

TABLE X: CALCULATE WEIGHTS RESULTS for RIVERS (LBA)

CLASS	AREA_SQ_KM	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	63.6122	42	-0.023853523	11.92805452	-11.95190804

TABLE Y: CALCULATE WEIGHTS RESULTS for SLOPE (LBA)

CLASS	AREA_SQ_KM	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	1.7219	0	0	0	0
1	7.8804	4	0.008382845	-0.000556366	0.008939211
2	**9.6285**	**10**	**0.724330101**	**-0.091151861**	**0.815481962**
3	10.2529	4	-0.254800258	0.019536527	-0.274336784
4	9.1385	6	0.265731849	-0.023853437	0.289585286
5	7.9678	3	-0.290330293	0.0167061	-0.307036393
6	6.9708	3	-0.156651331	0.008375356	-0.165026687
7	**6.6008**	**8**	**0.87872488**	**-0.08022131**	**0.95894619**
8	**5.9427**	**4**	**0.290599589**	**-0.016672567**	**0.307272156**
9	5.2719	1	-0.97592686	0.026598654	-1.002525514
10	**4.9908**	**3**	**0.177484155**	**-0.007966172**	**0.185450327**
11	4.6898	1	-0.858925733	0.021833829	-0.880759562
12	**4.6169**	**5**	**0.766187331**	**-0.044358912**	**0.810546242**

13	4.2187	2	-0.05991303	0.001993735	-0.061906765
14	**3.8449**	**2**	**0.03286686**	**-0.001042444**	**0.033909304**
15	**3.6132**	**2**	**0.095020982**	**-0.002919802**	**0.097940784**
16	3.4287	1	-0.545716192	0.011588218	-0.557304409
17	3.3259	1	-0.515275235	0.010757644	-0.526032879
18	2.966	0	0	0	0
19	2.737	1	-0.320396704	0.006012869	-0.326409573
20	2.4881	1	-0.225053275	0.004014228	-0.229067503
21	2.2393	0	0	0	0
22	1.9605	0	0	0	0
23	1.7619	0	0	0	0
24	**1.5166**	**1**	**0.269997679**	**-0.003748817**	**0.273746496**
25	1.2429	0	0	0	0
26	1.0198	0	0	0	0
27	0.8022	0	0	0	0
28	**0.7097**	**1**	**1.029389096**	**-0.010151079**	**1.039540175**
29	0.5411	0	0	0	0
30	0.3965	0	0	0	0
31	0.3388	0	0	0	0
32	0.2445	0	0	0	0
33	0.1854	0	0	0	0
34	0.1367	0	0	0	0
35	0.1068	0	0	0	0
36	0.078	0	0	0	0
37	0.055	0	0	0	0
38	0.0532	0	0	0	0
39	0.0352	0	0	0	0
40	0.0224	0	0	0	0
41	0.019	0	0	0	0
42	0.018	0	0	0	0
43	0.0132	0	0	0	0
44	0.0098	0	0	0	0
45	0.009	0	0	0	0
46	0.0185	0	0	0	0
47	0.0141	0	0	0	0
48	0.014	0	0	0	0
49	0.0139	0	0	0	0
50	0.0157	0	0	0	0
51	0.0151	0	0	0	0
52	0.0253	0	0	0	0
53	0.0273	0	0	0	0
54	0.0261	0	0	0	0
55	0.0225	0	0	0	0
56	0.0151	0	0	0	0
57	0.0098	0	0	0	0
58	0.0174	0	0	0	0

59	0.0165	0	0	0	0
60	0.0208	0	0	0	0
61	0.0198	0	0	0	0
62	0.024	0	0	0	0
63	0.0357	0	0	0	0
64	0.0184	0	0	0	0
65	0.0264	0	0	0	0
66	0.0422	0	0	0	0
67	0.0403	0	0	0	0
68	0.0343	0	0	0	0
69	0.039	0	0	0	0
70	0.0523	0	0	0	0
71	0.0282	0	0	0	0
72	0.0255	0	0	0	0
73	0.026	0	0	0	0
74	0.0232	0	0	0	0
75	0.0375	0	0	0	0
76	0.0309	0	0	0	0
77	0.0517	0	0	0	0
78	0.0691	0	0	0	0
79	0.0462	0	0	0	0
80	0.0879	0	0	0	0
81	0.1114	0	0	0	0
82	0.1263	0	0	0	0
83	0.0677	0	0	0	0

TABLE Z: CALCULATE WEIGHTS RESULTS for SOIL (LBA)

CLASS	AREA_SQ_KM	NO_POINTS	WPLUS	WMINUS	CONTRAST
0	0.7699	0	0	0	0
1	**20.4125**	**12**	**0.156707794**	**-0.032924191**	**0.189631984**
2	**4.4321**	**4**	**0.585372597**	**-0.029112209**	**0.614484806**
3	**2.7024**	**8**	**1.773273602**	**-0.11208093**	**1.885354532**
4	4.3876	1	-0.790837378	0.019316192	-0.81015357
5	1.6186	0	0	0	0
6	10.0703	5	-0.012204897	0.001041193	-0.01324609
7	7.6059	1	-1.340980224	0.045840998	-1.386821222
8	**5.8942**	**6**	**0.705743556**	**-0.051046273**	**0.756789828**
9	69.4427	27	-0.256718475	0.240261911	-0.496980386

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