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Assessing the effects of geomorphological processes on archaeological densities: a GIS case study on Zakynthos Island, Greece

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ABSTRACT

While geomorphological processes are considered key factors in the distribution of archaeological surface finds, few studies have attempted to quantify the relationship between artefact dispersal and erosional/depositional patterns. This paper compares Unit Stream Power Erosion Deposition model (USPED) and Revised Universal Soil Loss Equation (RUSLE) and integrates the results in the archaeological finds' density map of Zakynthos Archaeological Project. The study area (Palaiokastro), with artefacts dated from middle Paleolithic to medieval times, includes a steep terrain with a surrounding plain area, where the downslope erosion has considerably modified the distribution of archaeological remains. Through this study, it is possible to identify relationships between high artefact densities and stable/non-eroded surfaces, and on the other hand, low densities and eroded surfaces. However, the results indicate a degree of spatial variability, which modifies the predicted relationship. The consideration of the effects of these temporal and spatial patterns is crucial for developing effective sampling methods and accurately interpreting the archaeological record.

1. Introduction

Geomorphological processes are considered a key factor in the preservation and visibility of archaeological surface finds across the landscape (Ayala and French, 2005; Barton et al., 2002, 2010a,b; Butzer, 1982; Schiffer, 1983; Tartaron et al., 2006; Wells, 2001). The Mediterranean landscapes in particular, being dominated by steep topography and fragile soils, are predominantly prone to erosion, due to the existence of extensive droughts followed by high rainfalls (van der Knijff et al., 2000). As such, modern landscapes are characterized by the presence of thin soil cover on the slopes, while the resulting sediments can be found as colluvia and alluvia at the foot slopes and within the basins (Fuchs et al., 2009). At the same time, there is an emerging discussion on the distribution of archaeological assemblages (Brantingham et al., 2007, Butzer, 1982; Fanning et al., 2008; Schiffer, 1983, 1987; Tartaron et al., 2006; Wells, 1992; Wood and Johnson, 1978), in the sense that they are affected by a diversity of depositional and post-depositional processes. It is, therefore, suggested that geomorphic studies should be primarily incorporated in archaeological surveys in order to interpret the complex relation between ancient human strategies, geomorphic processes and surface exposure of archaeological finds (Ayala and French, 2005; Barton et al., 2002, 2010a,b; James et al., 1994; Wells, 2001).

This paper assesses the impact of soil erosion/deposition on the archaeological surface finds at the archaeological site of Palaiokastro and the surrounding setting (Zakynthos Island, Greece, (Fig. 1). The rationale of the study is that nowadays Zakynthos is characterized by scarce and fragmented archaeological data in comparison to the neighbouring Ionian islands and the mainland, while there is historical and archaeological evidence of habitation in several periods (Souyoudzoglou-Haywood, 1999, van Wijngaarden et al., 2005). The relative scarcity of archaeological remains on Zakynthos was hitherto attributed to the lack of systematic research. In addition to the few scientific explorations of the island, the current archaeological record is constituted through chance discoveries and rescue excavations by the regional archaeological services. During the reconnaissance survey of the Zakynthos Archaeology Project we were able to visit most of the known find spots, however, in several cases we established that known sites were no longer recognizable or had disappeared altogether (van Wijngaarden et al., 2005, 63–64). In this framework, recent geoarchaeological studies have attempted to interpret the scarcity of archaeological remains by demonstrating the

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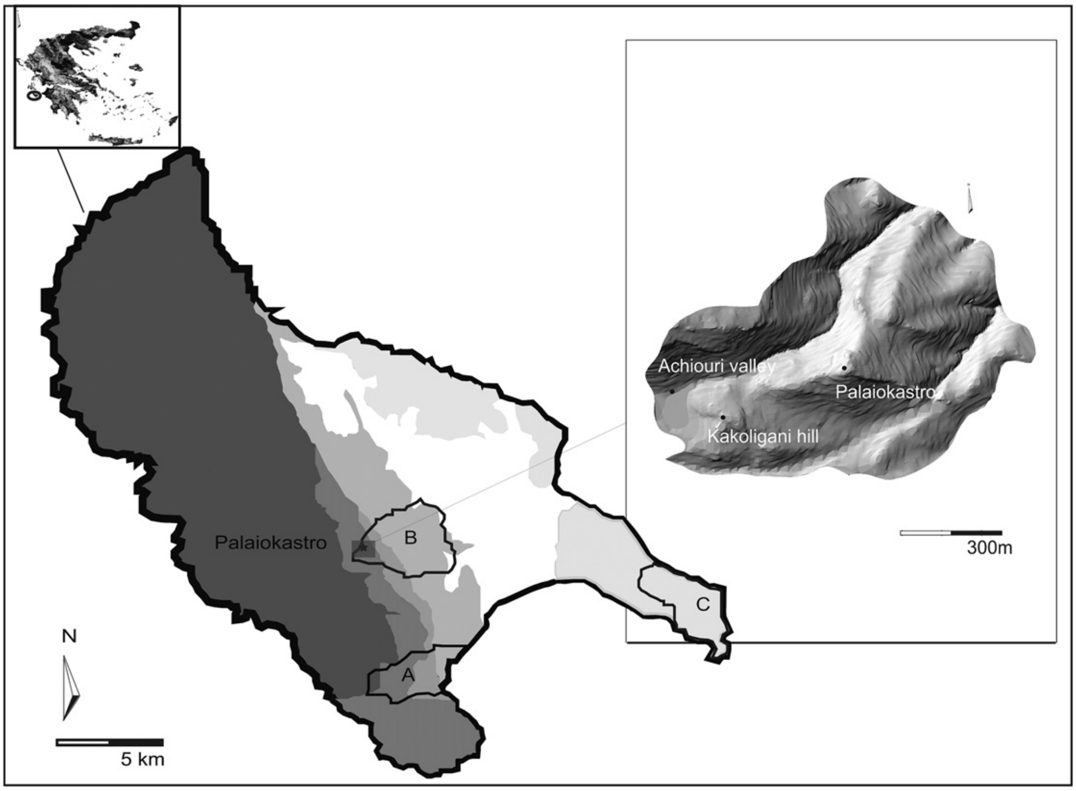

Fig. 1. Map of Zakynthos with indication of the 3 study areas (A, B and C) and map of Palaiokastro with indication of Achiouri valley, Kakoligani hill and Palaiokastro hilltop, respectively.

effect of landscape dynamics and intensive landuse practices to the preservation of the archaeological record (Dekker, 2007; Pieters et al., 2007; Storme, 2008; Tendürüs et al., 2008, 2010; van Wijngaarden et al., 2005, 2006, 2007, 2009, in press; van Wijngaarden, 2008).

The landscape of Zakynthos can be characterized as extremely dynamic due to the combination of strong tectonic and seismic activities, a long and specific history of intensive agriculture and intensive modern economic activities. These factors are thought to have strongly influenced the preservation of the archaeological record. What we now see on the surface and mostly what we do not see can be a result of the absence of the material, a non-exposure of the material (due to deposition) or a removal of the material, which was once there (due to erosion or human activity). What we aim to suggest is a model, which can incorporate the above dynamics to the interpretation of the archaeological record and simulate a discussion on the relation between ancient human strategies, geomorphic processes and surface exposures.

Therefore we comparatively applied two standard erosion models, Revised Universal Soil Loss Equation (RUSLE) (Wischmeier and Smith, 1978) & Unit Stream Power-based Erosion Deposition (USPED) (Mitasova et al., 1996, 1998) in a small-scale study area and incorporated their results on the surface finds distribution map of the Zakynthos Archaeological Project (Fig. 2). RUSLE is the most frequently used standard soil loss equation in soil sciences (Karydas et al., 2009; Kinnell, 2007; Kouli et al., 2007; López-Vicente et al., 2007; Millward and Mersey, 1999; Renard et al., 1997; Shi et al., 2004; Terranova et al., 2009; Yue-Qing et al., 2008) yet, lacking the capability to estimate deposition in concave parts of the landscape, it can occasionally have elusive results when applied to a complex Mediterranean topography (Hammad et al., 2004). USPED, on the other hand has been proven to provide a simple yet more realistic estimation of geomorphological processes (Barton et al., 2010a).

2. Regional setting

2.1. Geological background, vegetation and soils

Zakynthos is situated within sight of the Western Peloponnese (Fig. 1). The suitable harbours of the island make it a node in both regional and Mediterranean maritime traffic (van Wijngaarden et al., 2005). The geography of the island is dominated by the western mountain range, Vrachionas, which consists of Cretaceous limestone. The eastern part consists of a large fertile alluvial plain, Alikanas (Fig. 1). The location represents the transition from Eocene to Oligocene marly limestone formations (I.G.M.E., 1980), while Holocene terra rossa deposits are accumulated in the west plain. Maquis vegetation predominates at the slopes of the hills to the north and west, while natural sparse grasses grow between the bare eroded slopes of the hills to the west. The plains surrounding Palaiokastro are mainly cultivated with olive trees and some of the slopes are terraced for cultivation.

2.2. The archaeological survey

The Zakynthos Archaeological Project (ZAP) 2006–2010 is collaboration between the 35th Ephorate of Prehistoric and Classical Antiquities and the Netherlands Institute in Athens (NIA) and it is an interdisciplinary research programme, which incorporates a range of archaeological and geoarchaeological approaches. The aim of the project is to relate the spatial and chronological distribution of archaeological remains to the dynamics of the island's landscape. The core of the project is a comparison between three

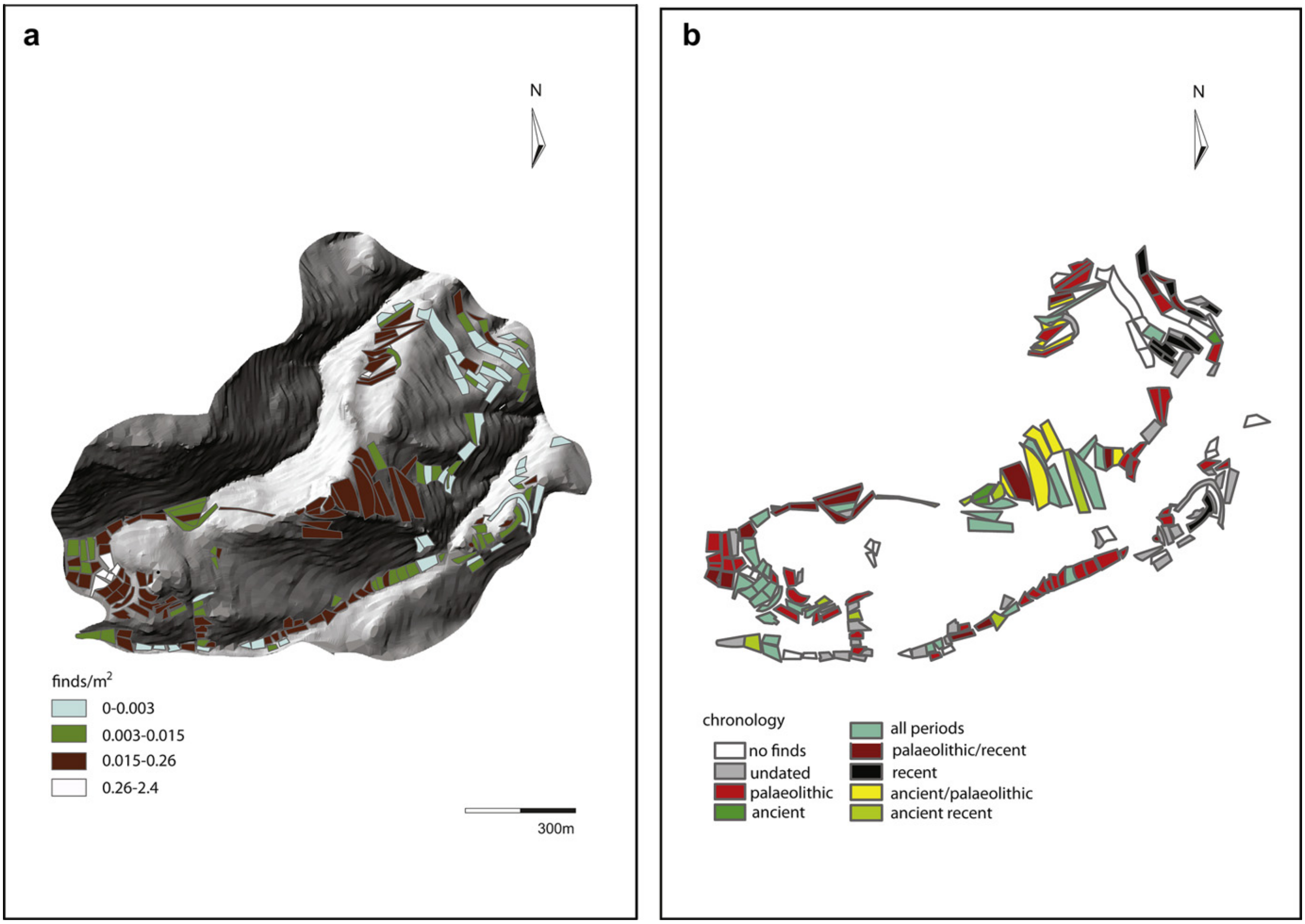

Fig. 2. a. Map of Palaiokastro indicating archaeological finds' densities (finds/m²). b. Archaeological tracts of Palaiokastro in chronological classes.

selected areas on the island (Fig. 1). These three areas are representative in terms of the main geological zones, while at the same time they vary substantially in terms of landscape types and topography (van Wijngaarden et al., 2005, 2006, 2007, 2009, in press; van Wijngaarden, 2008).

The methodology of the survey includes the pick up survey and the detailed geomorphological mapping of the study areas and has been adapted to suit the landscape characteristics, the topography and the artefact distributions. The basic analytical unit of the survey is defined as a tract, which is determined by topographic and geomorphic boundaries in the landscape and does not exceed 2500 m^2. The intensive and systematic survey methodology of the survey indicates that field walkers cover approximately 40% of all finds in each tract. Selected field tracts are occasionally revisited in order to assess the influence of seasonal factors on the survey results.

The intensive archaeological survey as practiced in the Zakynthos Archaeology Project is an adaptation of the general type of site-less survey, which is widely practiced in the Mediterranean (Caraher et al., 2006; Dunnel and Dancey, 1983). Archaeological surface survey has a range of uncertainties, originating in the many factors that influence the quantity and the nature of archaeological remains, which are documented by field walkers (Banning et al., 2006). For example, soil is sometimes transported and deposited in different fields. Rain, vegetation growth, erosion or earthquakes can seriously influence this indication of what is lying around in the fields at a specific time (van Wijngaarden, 2008). It is at this point uncertain to which extent all these find concentrations indicate archaeological sites. Some of them appear to be the result of sedimentation or of soil transportation for agricultural purposes.

The artefact densities are determined as quantities calculated according to the amounts of artefacts per square metres in each tract (van Wijngaarden et al., 2006: 31–33, 2007: 45–49). The above data are implemented in a GIS environment and are combined in a uniform database. In general, the archaeological record shows a high degree of destruction: relatively disperse distributions of archaeological materials (Fig. 2) and the finds themselves were very fragmented and worn (van Wijngaarden et al., 2005: 64–67). In a few cases (3 sites), architectural remains, have been identified, but finds related to the structure were absent at the surface. At other sites (27), architectural remains could be related to artefacts at the surface. This often applies to Byzantine, Venetian and Early-Modern ruins. Very few (9) ancient sites with standing architectural remains have been documented. The majority of the sites discovered during the Zakynthos Archaeology Project are concentrations of lithic artefacts and/or ceramics on the surface.

The archaeological data from Palaiokastro prior to the Zakynthos Archaeological Project come exclusively from the prominent hilltop. On the summit (Fig. 1), excavations from the 6th Ephorate of Byzantine Antiquities (Mylona, 1991) have yielded the remnants of a castle, including fortification walls, which has provisionally been dated to the 8th and 9th century A.D. To the northeast of the hill a small church was carved into a cave decorated with frescoes of the 11th–13th centuries. The preliminary results of the survey data (van Wijngaarden et al., 2005, 2007) yielded surface finds across the area, including lithics dated to the Middle Paleolithic (300–30 ka) and pottery sherds of the Early Bronze Age (3100/3000–2650 B.C.), Geometric (9th–7th centuries B.C.), Classical–Hellenistic (5th–2nd centuries B.C.), Roman (2nd

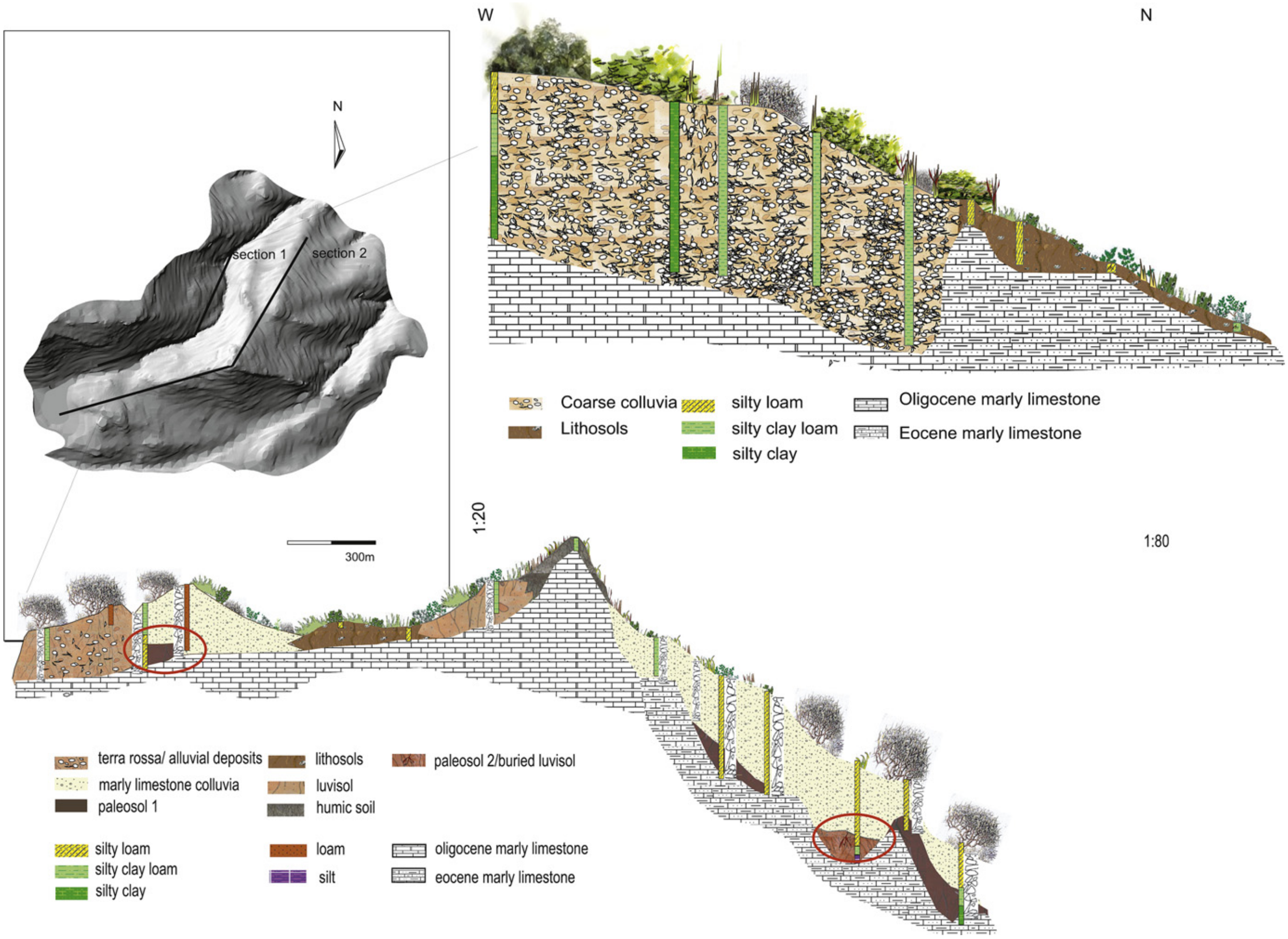

Fig. 3. The two cross sections and their location on the map. Paleosurfaces are shown in red circles in section 2.

century B.C.–4th A.D.) and Medieval times (4th–14th centuries A.D.) as well as recent finds (Fig. 2). The above data, though fragmentary, indicate that numerous spots of the study area have been subjected to intensive human activity at different periods in the past (van Wijngaarden et al., 2007, van Wijngaarden, 2008).

3. Materials and methods

3.1. Introduction

The aim of this paper is to simulate the surface processes dominating the study area and assess their effect on the preservation of the archaeological record. In order to do so we comparatively evaluate the results of two popular erosion models in order to decide on their applicability on dynamic Mediterranean landscapes. The assessment of the results is based on detailed geomorphological mapping of the study area. The results of the models are comparatively applied on the archaeological artefact distribution maps (Fig. 2), in order to test the hypothesis that the numbers of artefacts in the survey tracts are related to topographic factors and geomorphic processes.

3.2. Model selection and geomorphological assessment

The application of GIS-based soil erosion models has allowed the adequate representation and quantitative estimation of erosion and deposition processes at regional scale (Capolongo et al., 2008). Since the goal of this study is to suggest a GIS implemented erosion-mapping tool, which can be further integrated in intensive archaeological surveys, RUSLE and USPED equations were selected for their ease of implementation on GIS software, the reliance on easily accessible data and the accurate results.

The RUSLE has the ability to predict the long term average annual rate of soil erosion on a field slope as a result of rainfall pattern, soil type, topography, crop system and management practices, through the following equation (Renard et al., 1997):

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P$$

where A is the computed spatial average soil loss and temporal average soil loss per unit area (t/ha^{-1} year^{-1}), R is the rainfall-runoff erosivity factor [MJ mm/(ha/year^{-1})], K is the soil erodibility factor [ha MJ mm (t/ha/h/)], L is the slope length factor, S is the slope steepness factor, C is the cover management factor and P is the conservation support practice factor. Agricultural terraces are considered the dominant support practice on the site of Palaiokastro and were for this reason included in this study as P factor. L, S, C, and P are all dimensionless.

While the use of RUSLE is widespread in mapping erosion studies, it lacks the capability to compute deposition along hill slopes, depressions and valleys or in channels (Hammad et al., 2004). USPED equation, on the other hand, has been proven to

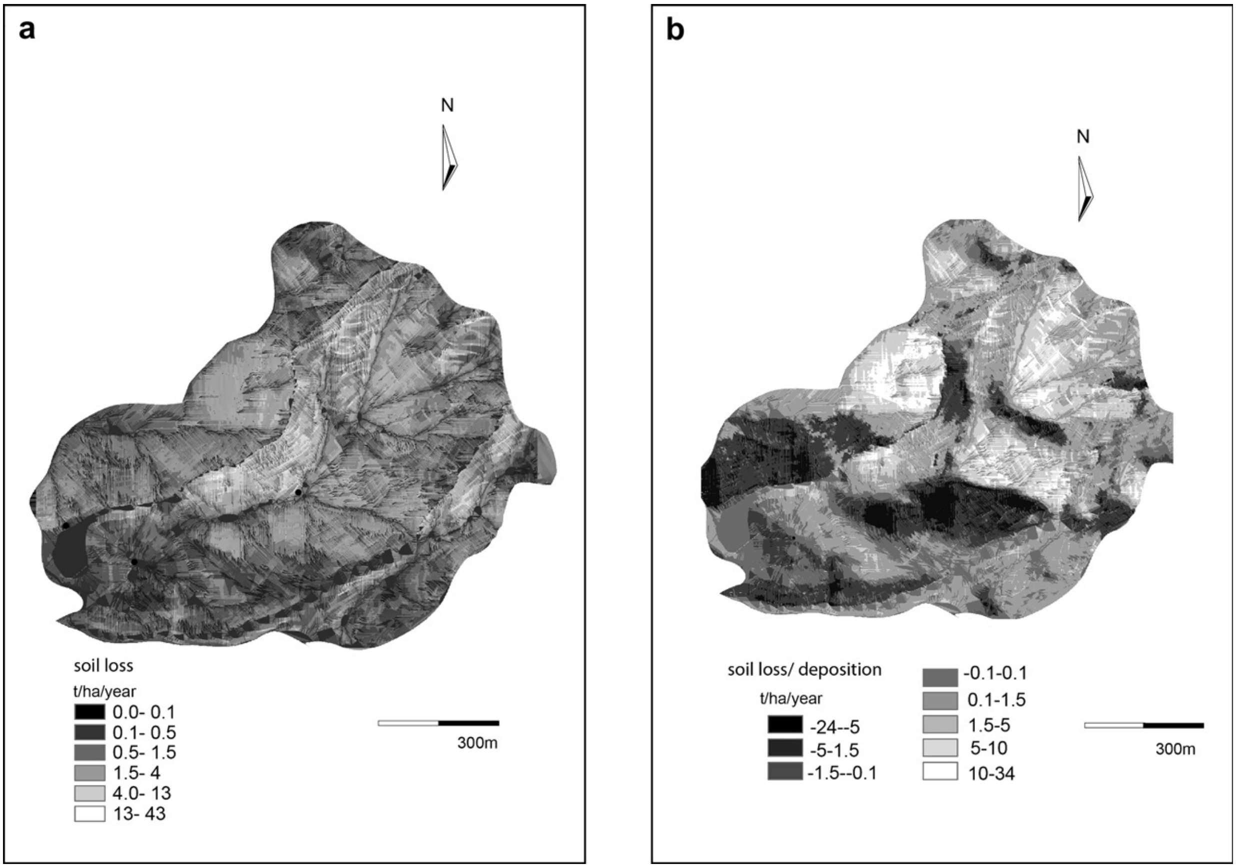

Fig. 4. a. Rusle map. High values represent intensive erosion and low values soil stability. b. Usped map. Positive values represent erosion and negative values deposition.

give more realistic results of surface processes simulation (Barton et al., 2010a; Capolongo et al., 2008; Liu et al., 2007; Pistocchi et al., 2003). USPED is a simple model which predicts the spatial distribution of erosion and deposition rates for steady state overland flow, with uniform excessive rainfall conditions (Mitasova et al., 1996, 1998). For the estimation of erosion and deposition (ED), which are both computed as a change in sediment transport capacity across a GIS grid cell, the following equation was computed:

$$\mathrm{ED} = \mathrm{d}((A\ \cos\ b)/\mathrm{d}x + \mathrm{d}(A\ \sin\ b)/\mathrm{d}y$$

where A is the upslope contributing area, b is the slope aspect of the terrain in degrees in the direction of the steepest slope. For the estimation of A, the Unit Stream Power Erosion and Deposition model (USPED) has the basic model structure of the RUSLE.

For assessing the results of erosion/deposition patterns of RUSLE/USPED models, a soil map was constructed based on two stratigraphic sections and 82 soil samples collected form throughout the study area and analyzed for granulometric and thermogravimetric analysis (Fig. 3). Moreover, two paleosurfaces were identified; paleosol 1 was relatively dated according to the archaeological finds found in it, while paleosol 2 was dated using OSL technique.

3.3. Measuring the effect of geomorphology and topography on archaeological finds

Archaeological record preservation and visibility in Zakynthos are thought to have been effected by a number of factors including erosion/deposition processes and topographic factors such as slope steepness, vegetation and landuse practices. In order therefore to test the effect of the above topographic and geomorphological processes on archaeological artefacts distributions in Palaiokastro, we applied the erosion/deposition model results and their topographic factors (LS slope, P landuse practices, C vegetation) to the archaeological tracts (Fig. 2). More specifically the topographic and geomorphic variables were reclassified into two classes of low/high values and were compared with classes of low and high artefact density respectively. Four possibilities were tested: a) high variable/high density b) high variable/low density c) low variable/low density d) low variable/high density.

4. Results

4.1. Erosion/deposition model comparison and geomorphological evaluation

RUSLE map (Fig. 4) demonstrates stable or low erosion conditions at the plains of Palaiokastro and on the plateaus of the ridges along the hilltops. Moderate erosion is identified on the lower and gentle slopes, high erosion on the majority of the hill slopes, while very high erosion values are only observed locally. On the other hand, USPED map (Fig. 4) shows mainly deposition patterns at the western slopes and plains, while for the majority of the east and northeastern half of the study area the map indicates low to moderate erosion values, which do not exceed generally 10–15 t/ha/y. According to the RUSLE map, the majority of Palaiokastro study area is within erosion class 4, which represents soil loss of 1.5–4 t/ha/year. The less spatially extensive class is 6 with soil loss values above 13 t/ha/year. For the USPED map, class 5 is the most

extensive (0.1–1.5 t/ha/year). The least widespread class is 8, with values above 10 t/ha/year.

The results of erosion/deposition patterns of RUSLE/USPED models were compared to the soil map (Fig. 5) (for the description of the sedimentological units see Table 1). Here, it is shown that USPED offers a more realistic estimate of the actual geomorphologic conditions of the study area. Generally the distribution of colluvia on the soil map is broadly coinciding with areas of deposition on USPED, the distribution of thin soils with areas of erosion, whereas distribution of developed soils coincides with areas of soil stability.

Two buried soils have been identified at the foothill of Kakoligani hill and at the eastern part of the study area, respectively (Fig. 3). Paleosol 1 found at the foothill of Kakoligani hill is relatively dated at the Hellenistic period based on pottery and in situ construction material included in the layer. Paleosol 2 comprises of 3 different horizons, which have been dated by OSL at 12.2 ka, 8.3 ka and 1.6 ka, respectively (report by Jakob Wallinga and Candice A. Johns, TU Delft University of Technology).

4.2. Applying geomorphology and topographic variables on archaeological distributions

The geomorphological processes and topographic factors identified for each of the archaeological tracts show a number of recognizable patterns (Fig. 6). More specifically high archaeological find densities on stable/deposition areas are mainly concentrated at the Achiouri plain and the plains at the south of the study area. On the other hand, low archaeological densities on high erosion areas are mainly concentrated on the eastern part of the study area. High densities on high erosion areas are located on the Palaiokastro hill and at the foothill at the northwest of Palaiokastro, while low densities on low erosion areas are scattered throughout the study area. Very similar remarks can be made for the RUSLE map (Fig. 6). However, the patterns in this case are less evident, mainly in the eastern slope area, where low densities are equally distributed in areas with low and high erosion values, respectively.

The vegetation cover factor *C*, which is related to the visibility of the archaeological artefacts shows a variety of patterns related to archaeological densities (Fig. 7) i.e. similar percentages of high and low archaeological concentrations are found in both low and high vegetation cover. Comparable patterns are identified in the slope steepness factor (LS factor), where high densities can be found in many cases in both low and high steepness. For the *P* factor/density map it is interesting to note that most of the high densities are concentrated on areas that are not terraced (Fig. 7).

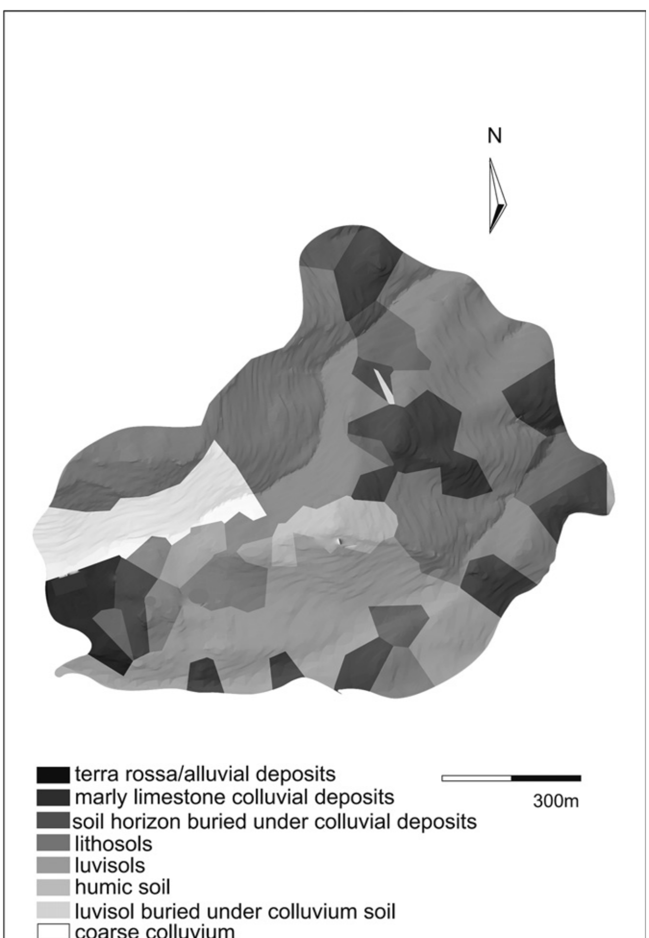

Fig. 5. Soil map of Palaiokastro based on the extrapolation of two cross sections, description of exposed profiles and analysis of 82 soil samples.

5. Discussion and conclusion

5.1. Assessment of soil erosion and soil formation

It is estimated that 36% of the total study area is yielding a rate of erosion above 0.5 t/ha/year and this is the maximum amount of erosion that allows soil formation (Lehman, 1993). Moreover, 27% of the study area exhibits erosion rates above 1 t/ha/year and according to the European soil erosion risk assessment (van der Knijff et al., 2000) this erosion rate can lead to irreversible soil degradation conditions, within a time span of 50–100 years. In other words, one-third of the study area, basically the eastern part, will exhibit in the following years considerable soil losses, which can occasionally be followed by the washing down of the thin remaining fragile soils and the exposure of the underlying parent material, a process which is already visible in certain parts of Palaiokastro hill.

On the other hand, well-developed soil profiles are generally identified in relatively limited extent. The chronology of paleosurface 2 indicates soil stability conditions at 12.2 ka to 8.2 ka, with a later formation at 1.6 ka. (Fig. 3) The first chronology can cautiously suggest the existence of environmentally stable conditions during the late Pleistocene and in this way the soil horizon can be tentatively related to the abundance of prehistoric lithics all over the study area. The 1.6 ka dating coincides with the very beginning of the late Bronze Age and therefore can be associated with the identification of scatters of Bronze Age pottery. This soil was formed as a “pocket” in a small depression created in the limestone bedrock. These depressions provide the required conditions for soil formation and at the same time protection from intensive erosion. At a later stage, certainly after 1.6 ka, the soil was sealed with colluvial deposits. The sharp boundary between the two units represents either an abrupt change related to an excessive runoff, as a result of environmental changes, or it suggests that the soil was artificially covered with colluvium when constructing the agricultural terraces, since this is frequently used as terrace infill.

Paleosurface 1 (Fig. 3) is relatively dated to the Hellenistic period and is covered with a thick colluvium deposit, which is tentatively related to the construction of the agricultural terraces and was therefore possibly transported by man to the threads of the terraces. In this case the possibility that this area has been terraced at a time closely post to the Hellenistic period cannot be excluded.

The construction of agricultural terraces in Palaiokastro has provided additional agricultural land in an area with restricted

Table 1
Summarized description of sedimentological units.

Unit no	Tracts	Thickness min–max (cm)	Colour	Lithology	Organic matter (%)	$CaCo_3$ (%)	Inclusions
1	4024, 4008 4014, 4028, 4021	185–200	(bright) brown (7.5 yr 4/6, 10 yr 4/6, 7.5 yr 4/5.6–8), bright reddish brown (5 yr 5/8), light yellow orange (7.5 yr 8/4), orange (7.5 yr 7/6), with layers of dark reddish brown (5 yr 3/4) in 4024, 4014 and 4021	Silty clay, silty clay loam and silty loam with coarse gravel to cobbles and stones. Phi value ranges from 6.7 to 8.5 falling into the fraction of fine silt to clay. Standard deviation is 1.9 –2.42 indicating poorly sorted material. Skewness is generally negative and distribution bimodal	0.7–4.5	2–5. Tracts 4021 and 4014 reach 91	
2	4088, 4087, 4086 and 4084, 4009, 4010	20–50	Bright brown (7.5 yr 5/8), reddish brown (5 yr 4/6), brown (7.5 yr 4/4)	Silty clay loam to silty clay moderate to very stony including fine to coarse gravel. Phi value is 1.79–8.3 falling into the very fine to fine fraction. Standard deviation ranges from 1.79 to 2.3 indicating poorly sorted samples. Skewness is negative and distribution is bimodal	2.2–6.2	2.5–7.7, tract 4088 10–36	Fine roots
3	4075, 4043	10–30	Brown (10 yr 4/6) to dark reddish brown (5 yr 3/2)	Silty clay loam and loam, slightly stony to very stony consisting of medium to coarse subangular gravel. Phi value is 5.37–7.48, falling into the fraction of medium silt to very fine silt. Standard deviation ranging from 2.44 to 2.9 indicates very poor sorting. Skewness is positive and distribution is bimodal	5.8–7.9	18.3– 28.2	Fine roots
4	4044, 4019, 4046, 4047a, 4047b, 4004, 4002 and 4095	90–215	Dull yellowish brown (10 yr 5/3) in tract 4044 and light gray (10 yr 7/1, 6/1)	Silty clay loam, silty loam and loam, slightly to moderate stony, including fine to coarse gravels. Phi value ranges from 5.3 to 6.8, falling into the fraction of medium to fine silt. Standard deviation values, ranging from 1.87 to 2.46, indicate poorly sorted to very poorly sorted samples. Skewness is slightly positive from 0.01 to 0.1, indicating relative symmetry of the distribution, which is mainly unimodal and occasionally bimodal	1.29–4.6	40.21–82.41	Fine roots
5	4044, 4047, 4002 and 4095	20–60	Dark brown (10 yr 3/3-4), dull yellowish brown (10 yr 5/3), brown (10 yr 4/4)	Silty clay, silty clay loam and silty loam with fine to coarse gravels and occasionally very stony. Phi value ranges from 5.74 to 7.9, into the medium silt to very fine silt fraction. Standard deviation values fluctuate from 1.68 to 2.82 indicating poorly sorted to very poorly sorted matrix. Skewness is generally positive, with only one negative example (4095). The distribution of the samples is generally bimodal and only tract 4047 is demonstrating unimodal distribution	1.3–4.5	7.8–57	
6	4068, 4034 and 4031	10 and 1.10	(Very) dark reddish brown (2.5 yr 2/4, 5 yr 4/8, 5 yr 3/6)	Clay, silty clay to silty clay loam, moderate stony with medium to coarse gravels angular to subangular. Phi value is between 7 and 8, and therefore is in the very fine silt to clay fraction, and the standard deviation is between 2 and 2.8 indicating very poorly sorted material. Skewness is mainly negative and distribution is smoothly bimodal	3–9	2–7	
7	4069, 4070, 4071	30	Brownish black (5 yr 3/1)	Silty loam, moderately stony with fine to coarse subangular gravels. Phi mean value is 6.5 and falls into the fraction of very fine silt. Standard deviation is 2.34 indicating A very poorly sorted sample. Skewness is positive and the distribution is slightly bimodal	17	3	Fine roots
8	4003	50	Olive brown (2.5 yr 4/6), reddish brown (5 yr 4/6), dull yellowish brown (10 yr 4/2)	Silt, silty clay loam, silty loam with fine to coarse gravels, angular to subangular in moderate quantity. Phi value is 7.05 and it is therefore in the very fine silt fraction and the standard deviation is 1.85, which is poorly sorted. Skewness is positive and distribution unimodal	3.8–4.7	2.3	Fine to coarse roots and moderate quantity of flint

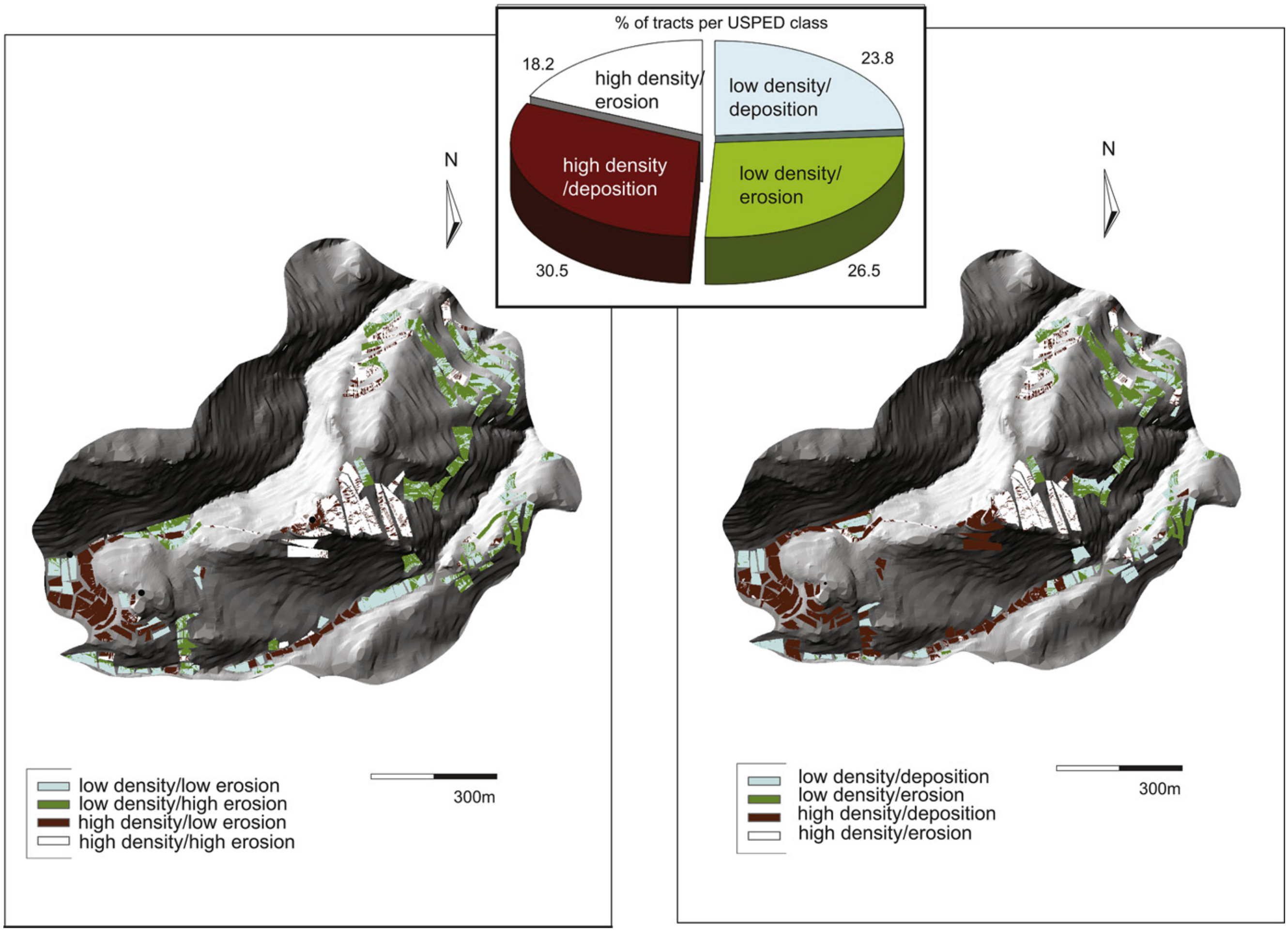

Fig. 6. Overlay maps of RUSLE and USPED to archaeological densities. The chart pie indicates the percentage of tracts per USPED class.

availability of cultivatable terrain. This practice is still continued today and it is furthermore noticed that bulldozed agricultural terraces are constructed at the south of Palaiokastro summit. The abandonment of some of the terrace walls is possibly related to the fact that these walls were built in inaccessible areas, which cannot be reached through any of the modern road cuts. In these cases, the abandonment of the walls was not followed by intensification of erosion as it has been attested in abandoned terraces (Inbar and Llerena, 2000). On the contrary, it is suggested that the fast regeneration of vegetation has provided additional protection to the soil and therefore this part of the landscape is now characterized by a relative stability in relation to non-terraced adjacent slopes.

5.2. Soil erosion and archaeology distribution in Palaiokastro

At Achiouri valley, the USPED/archaeological densities map displays high densities related to stable/and or depositional areas. The surface finds in this area indicate a mixture of pottery sherds from different chronological periods (prehistoric to roman and modern), while most of the corings carried out by the ZAP project at the west plain, reaching a maximum depth of 188 cm, do not demonstrate any clear stratigraphy, confirming the surficial mixture of finds (van Wijngaarden et al., 2007). van Wijngaarden et al. (2007) suggest that concentrations of material to the west valley could originate from a site spot at the lower slopes, and this possibility is further supported by the indication of intensive erosion (Fig. 4) at parts of these low hills. However, these inferences, do not exclude the possibility for the existence of in situ material preserved in these lower plains. As discussed above, paleosol 1 is located at this location, which suggests that the west and south plains of Palaiokastro represent both catchments of eroded material (mainly of lithic tools, probably originating from the slopes to the north (van Wijngaarden et al., 2007) and locations of in situ clusters. The study of the surface material in this case can be relatively problematic, since both the secondary and in situ deposits must have been severely disturbed from post-depositional agricultural and landuse activities in the area. Useful information can be derived from the profiles of the terraced slopes, as the "agricultural terrace infill" can occasionally bury in situ artefact clusters (Krahtopoulou and Frederick, 2008).

A second pattern indicates low archaeological concentrations in areas of high erosion at the eastern slopes of the study area (Fig. 6). The current scarcity of artefacts could suggest that archaeological material was never accumulated in these areas and this hypothesis is further supported by the absence of high densities on slightly eroded adjacent spots. Furthermore, high densities on high-eroded surfaces are indicated at the hill of Palaiokastro and at the foothill at the northeast of the study area (Fig. 6). On the hilltop of Palaiokastro, intensive soil erosion has left the surface remains of the medieval castle as "lag" deposits. The erosional episodes in Greece related to historical times are generally considered less catastrophic than those of the prehistoric times (Bintliff et al., 2005). It has been suggested that the net effect after 50–100

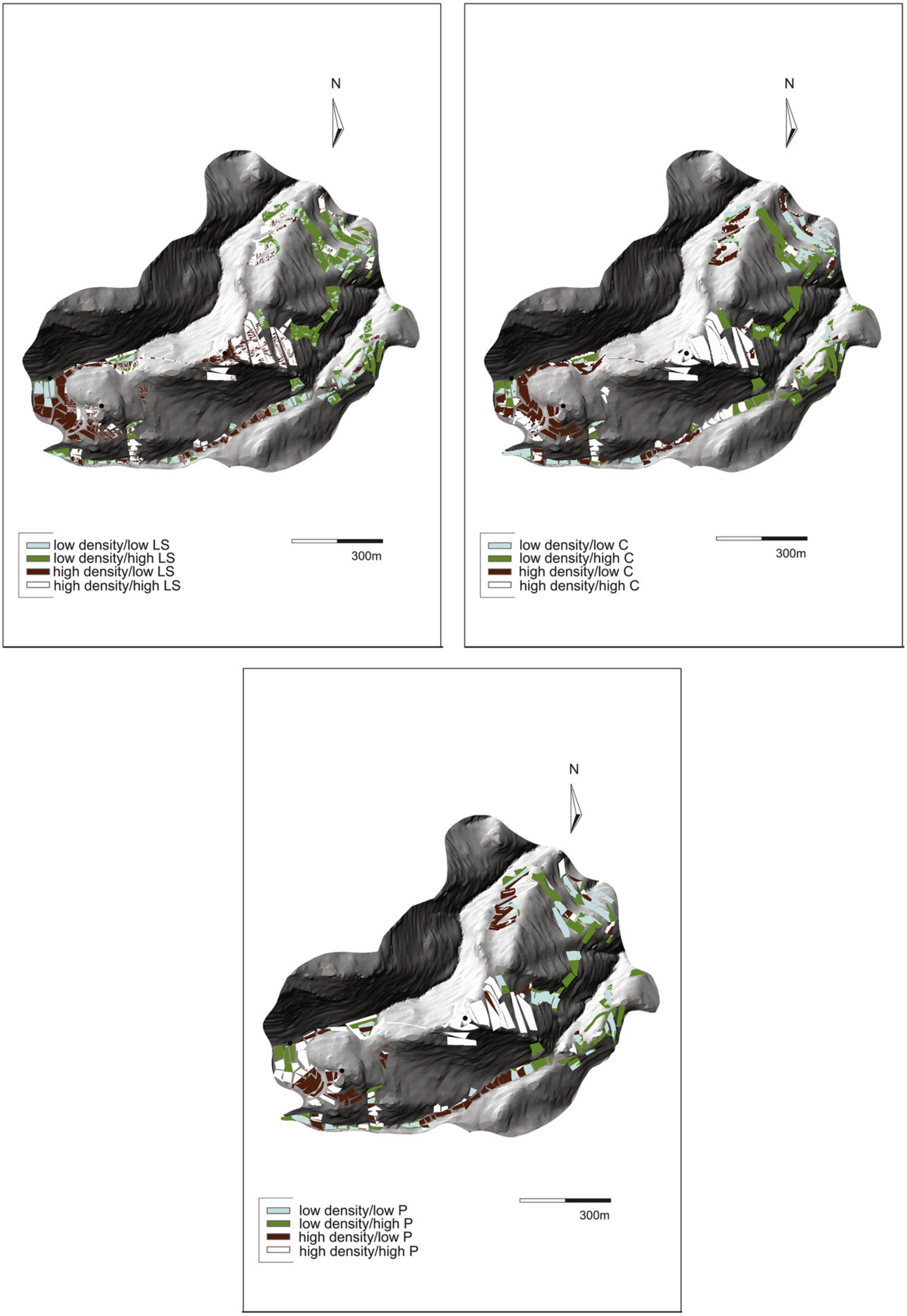

Fig. 7. Overlay maps of LS (slope), C (vegetation) and P (agricultural terraces) factors to archaeological densities.

first years of abandonment of a site is the increase of artefacts visibility; thereafter the sherds decrease exponentially in relation to the topography and the influencing erosive factors (Kirkby and Kirkby, 1976). It should be noted that the association of high densities/high erosion surfaces with potential sites is far from straightforward and that each of the different cases should be examined and interpreted individually. This observation is significant, given the fact that sediment transport around the slope, as part of the construction of agricultural terraces, is thought to disturb in a great extent the original position of sediments and has serious implications for the visibility of archaeological finds (Krahtopoulou and Frederick, 2008).

Examining the different parameters of erosion, it is interesting to note that LS factor is considered to have a weak effect on the distribution of archaeological material (Fig. 7). Mainly it is indicated that high densities can be found in many cases in both low (31%) and high (27%) slope steepness. It should, however, be noticed that the slope gradient in Palaiokastro has been severely distorted by the construction of agricultural terraces, which has significantly modified the morphology and steepness of most sharp and moderate slopes. Generally, it is considered that downslope movement is decreased as slope decreases, until the point, where an object will not continue downslope (Rick, 1976). The shear force acting on a standard particle lying on a 30° slope is 1.9 times bigger than that of 15° and 5.7 that lying on 5° (Reid and Frostick, 1985). This, moreover, depends on the weight of the distributed material (Rick, 1976). Experimental research carried out by Rick (1976) in Peru has shown that lighter objects will come to rest on steeper slopes, heavier objects will continue towards gentler slopes, while for any given weight there is a slope angle below which that material will not move. According to the same study, lithics tend to be found in relatively larger numbers at the bottom of the hills than ceramics and this is the case in Palaiokastro, where most Paleolithic finds are concentrated in Achiouri valley and the valleys to the south of Palaiokastro hill.

From the *P* factor/density map (Fig. 7), it is attested that in a percentage of 34%, most high densities are concentrated in areas that are non-terraced. This remark implies that the terraced locations are either heavily distorted, (in the case of bulldozed terraces), or that the archaeological material is buried under the "terrace infills". In this case the recording of surface finds can lead to elusive inferences concerning the reconstruction of the archaeological record and in these cases subsurface testing is essential to determine the representativeness of site distributions recorded by surface surveys.

Another major factor influencing the survey results is the vegetation cover, which obscures artefact visibility (Banning et al., 2006; Bevan and Conolly, 2004). The visibility is particularly important for the reliability of the quantitative data and in several archaeological field projects raw artefact counts are statistically improved to compensate for a loss of data due to vegetation cover (Bintliff et al., 2001). Pieters (2008) has shown that for the artefact counts of the 2006 and 2007 campaigns of the Zakynthos project, there is no positive correlation with vegetation cover. It seems that the vegetation cover surely influences the quantitative data of the survey, but it appears to us highly doubtful whether this can be corrected by statistics.

The *C* factor of the USPED map (Fig. 7) verifies the above results showing that that there is not any significant correlation between vegetation cover and artefact concentrations and that high densities are found in low and high vegetation cover in similar percentage of cases (28 and 31% respectively), while low densities are seen in low and high vegetation cover in exactly the same percentage (21%). A way to understand better the effect of vegetation cover on artefact count is to revisit certain areas over a longer time span and consistently document the changes in vegetation cover and artefact count. From 2007 to 2010, specific tracts in research areas B and C were revisited in spring, summer and autumn.

This practice has shown that even when the vegetation cover remains somewhat the same, artefact counts can still vary significantly. Apparently, vegetation is not a predictable variable with regards to survey finds. One reason for the difficulty to assess the role of visibility through vegetation appears to be the fact that vegetation growth and agricultural practices do not always result in clear seasonal cycles of surface visibility. This indicates that it is not possible to detach vegetation growth from the many other factors that influence the detection of archaeological artefacts on the surface. The many factors that influence the results of the surface survey show that we should be aware that we never document a full or representative picture of the archaeological surface record.

6. Conclusion

The above study has confirmed that one-third of the study area will exhibit considerable soil losses in the following years, which can occasionally be followed by the washing down of the remaining fragile soils and the exposure of the underlying parent material. Two years after the completion of this study, in August 2010, Palaiokastro was subjected to severe fire, which is expected to exacerbate the erosion potential by altering soil and vegetation properties and raising runoff up to double within one year (Johansen et al., 2001; Moffet et al., 2007; O'Dea and Guertin, 2003; Soto and DÌaz-Fierros, 1998).

The effects of downslope erosion and deposition on archaeological finds confirm the significance of quantifying these processes within archaeological surveys. USPED has been proven an accurate simulation tool for this purpose, whereas, the application of the model within a limited study area has been valuable for the evaluation and refinement of the results. This study by no means suggests that erosion/deposition models should be used as tools for making one-dimensional associations between natural and anthropogenic processes. The above patterns are originating from a number of factors, which should be taken into account, when interpreting human activities in their natural context. The way these data relate to cultural practices in the past is a challenging interpretative step.

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