Studying the Ancient Settlement of Hacilar Büyük Höyük with Integrated Methods

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Highlights:

• The archaeological structures buried underground are displayed by utilizing GPR.
• Geomorphological units are determined via SVF and RRIM in the GIS environment.
• The effects of dry farming, site-tethered pastoralism is discussed by using an ABM.

Keywords: agent-based modelling, geophysics, Hacilar Büyük Höyük, morphometric analysis, remote sensing.

BACKGROUND

The potential of Remote Sensing (RS) for archaeological surveying in terms of extracting significant information about both the subsurface and the landscape is well evidenced in recent work. Joint interpretation of aerial and ground-based remote sensing has been shown to enhance understanding of settlement characteristics and their relation to the environment. This study focuses on a multi-methodological analysis of the Hacılar Büyük Höyük site in south-western Anatolia (Burdur, Turkey), which is of crucial importance for understanding the Early Bronze Age I (c. 3100-2900 BC) in Anatolia (Umurtak & Duru, 2012; Duru, 2017). A detailed plan of the settlement on the mound exists already thanks to extensive long-term archaeological excavations. The unexcavated part of the site was investigated with ground penetrating radar (GPR) to locate archaeological structures and a morphometric analysis in a GIS environment was carried out to determine geomorphological units. In a final step, an agent-based model (ABM) was adapted to compute the long-term impacts of agropastoral land use covering both natural changes and the impact of human decisions.

METHODOLOGY

Geomorphological units around the settlement were studied using ArcGIS (Esri Inc., 2020) and SAGA GIS (Geographical Information System) (Conrad et al., 2015) to provide a better understanding of the landscape. Sky-view factor and red relief image mapping (RRIM) (Chiba et al., 2008) techniques were applied for both the mound and the settlement to visualize simultaneously topographic slope gradient and curvatures (Fig. 1). Tentative archaeological ruins observed on the mound were investigated by morphometric analysis while archaeological ruins hidden below the surface in different cultural layers were measured with morphometric analysis. The GPR data was processed using GPRSlice (Goodman, 2017) and uploaded to a QGIS database.

GPR measurements and morphometric analysis, accompanied by an archaeological ground survey, contribute data for visualizing the subsurface and developing a landscape evolution model in order to be able to predict socio-ecological dynamics around the settlement. Computer simulations provide an environment that makes explicit the archaeological assumptions, creates experimental approaches to answer specific research questions.
and increases the spatial and temporal resolution of the archaeological record.

The MedLand Modeling Laboratory (MML), an agent-based model developed by Arizona State University (Barton et al., 2013), is used to study long-term human–environment interactions around settlements and visualize impacts of social and natural processes on the environment. The ABM is a simulation technique that provides an understanding of how a structure with collective features derives from the behaviour of its components. These components are called ‘agents’ making rule-based decisions with a certain degree of randomness. The agents within the MML are agropastoral households comprised of a determined number of individuals, which are, as households, part of a village; thus determining the distance to resources. Farming and grazing activities in stochastic models are distributed randomly and the suitability of specific patches of land to these activities are calculated by GIS routines. Cultivation requires alterations on naturally occurring vegetation for providing enough biomass to humans, that is, subsistence-strategy decisions made this year are dependent on the results of the previous year. Each household is attached to the village to increase the survival rate. The choices made in the beginning enable the model to compute the village population, the amount of cultivated and fallowed land, and total annual yield. Different population scenarios can be tested in different climatic conditions derived from the Macrophysical Climate Model (MCM) in woodland environments. The MML integrates several approaches for visualizing land use; thus, it is stochastic to some extent. The GIS-based model displays how natural factors contribute to the changes in the landscape. In the model, the dominant surface processes are soil and vegetation resistance to detachment of sediment by flowing water (Barton et al., 2010). The GRASS script uses several landscape parameters such as the C-factor (vegetation erosion protection) and K-factor (soil erodibility), in addition to MCM results such as annual precipitation, the number of rainy days, an average of precipitation per rain event, and rainfall intensity.

The simulations for this study were conducted for the 200 years between 3100 and 2900 BC corresponding to the Early Bronze Age I. The remote-sensing techniques together with current archaeological knowledge of the surrounding area helped to create the population input data by visualizing the pattern of buried households. An abstract representation of the landscape was defined with the Geographic

Figure 1. Visual assessment of the topography of the Hacılar Büyük Höyük mound: sky-view factor map (left) and red relief image map (right).

Results

Several remarkable features around the mound not observed in the raw data were identified in the RRIM images. Geomorphological units were identified using these maps, and the interaction of the environment and human beings was interpreted by a combination of applied methods. Geophysical results also revealed significant information about the main characteristics of the mound. The GPR results showed the same pattern of casemate walls as revealed in the archaeological excavation, continuing along the mound boundary (Fig. 2). Semi-circular units, previously not excavated, were traced next to these walls. In the MML, four scenarios with ten iterations in each were simulated for the 200 years covered in the study, and the cumulative effect of anthropic changes and fluctuations of the precipitation on the vegetation and surface processes was calculated. The MML model maps and calculates anthropic impact on vegetation around the site at 10 m² resolution (Fig. 3). It is affected by the intensity of activities, duration of the scenarios, and the nature of the environment around the site. The given properties of the population behave as a disturbance in that area; therefore, land cover type was used to determine the length of succession stages indicating the recovery time of the vegetation and type of climax community. Each cell on the map has an assigned value of 1 through 35 for the woodland environment and all landscape patches start at 35 and are reduced during the simulation, depending on the applied disturbance. While the tall shrub steppe and sparse trees vegetation class with minimum disturbance are represented in green, black corresponds to a total removal of vegetation from the cell. In terms of agropastoral strategies of the settlement, removal of land cover caused by grazing and farming activities creates an intensive impact zone around the settlement. The next step in the study was to calculate how much of the vegetation is replaced by cultivated grain in order to measure the agricultural impact on the environment. Measurement of net vegetation change caused by grazing activities derives from the volume of grass removed by grazing, which factors in the time needed for vegetation to be regenerated within a cell.

Conclusion

The integration of GPR results and aerial photographs led to the tracing of tentative archaeological remains that engendered further geophysical and archaeological surveys. The aim of the GIS analysis was to detect possible marks on the surface and to understand the general disposition of geomorphological features on the mound and around it.
Visualizing the households as much as possible can provide more realistic assumptions on the population data used in the model and this shapes land-use needs in terms of subsistence strategies because of the change in variables over time, e.g., total annual yield, number of ovicaprids, and wood gathering intensity. The results of the modelling experiments give an improved and more detailed understanding of socio-political and environmental processes taking place in the settlement. The scenarios generated for the 200 years under study display how cultural impact on the environment could have shape the vegetation. The application of agent-based models to this single-period settlement also provides insight into the long-term dynamics of socioeconomic and demographic transition.

References


