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Quantitative GIS-based analysis of archaeological data of the archaic state of Tell Mardikh/Ebla (3rd millennium BC): the Big-DEA project.

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Abstract. The paper provides an overview on Big-DEA, a multidisciplinary project aimed at developing a comprehensive multi-level explanatory model for the development of an archaic State in the ancient Near East, using the exceptional case of Tell Mardikh, ancient Ebla (Syria), during the second half of the 3rd millennium. The project's goal is the reconstruction of the archaic state organization through an integrated analysis of archaeological and epigraphic data. The interaction between humanities and hard sciences is adopted in order to build a multi-tier explanatory model regarding the territory under the control of the Ebla kingdom, considering anthropic and environmental data deriving from excavations, survey and textual sources. The way to managing and study such a large Big Data archive, which includes different datasets, is itself the main challenge of the project: the creation of a dedicated relational database management system (RDBMS) functional to the implementation of the available GIS platform and the development of an appropriate simulation framework.

1. Introduction

This paper presents the Big-DEA project (Big Data and Early Archives. Measuring Settlement Dynamics and Environmental Exploitation in the Ebla Region during the 3rd Millennium BC: Archaeological Record, Cuneiform Texts, and Remote Sensing), a research aimed at developing a comprehensive multi-level explanatory model for the study of archaic States in Western Asia during the 3rd millennium BC, by using the case-study of Tell Mardikh/Ebla in Northern Syria.

The main goal is to research the quantitative variables of the economic and socio-political structure of the Ebla kingdom, including the multi-scale interrelations with the area under its influence: site level (Ebla, capital city); the territory beyond it (*chora*); the region interested by the Ebla network of exchanges and interactions. The large amount of archaeological, textual, and environmental data collected during the several campaigns of work at Ebla make this site and its territory a unique case to test the rise and the collapse of a vast kingdom of the Early Bronze Age. One of the main challenges of this program is to study such a large Big Data repository within a broad geographical framework, which encompasses from archaeological excavation, cuneiform written sources from the Royal Archive, environmental studies.

Big-DEA is leaded by University of Milano (PI Luca Peyronel) in collaboration with the Research Units of the University of Bologna (Geomatics, Remote Sensing and GIS processing), the University of Florence and the Italian National Research Council - CNR (textual data). The project is funded by the Italian Ministry of University and Research – MUR within the framework of Italian Research Projects of National Relevance PRIN 2017.

2. Research context: the site of Tell Mardikh/Ebla and its environment

Tell Mardikh-Ebla is a ca. 60 ha site located 55 km SW of Aleppo, about 400 m asl. Since the late 60's, the site has been the subject of a long-term investigation program by the Missione Archeologica Italiana in Siria – MAIS, Sapienza University of Rome, under the direction of Paolo Matthiae. The site became particularly known in 1974-1975 thanks to the unique discovery of a state archive containing ca. 17,000 clay cuneiform tablets from the Royal Palace G [1,2]. The archive is dated to the Early Bronze Age IVA (level IIB1, 2400-2300 BC), when Ebla was the capital of a kingdom covering a large portion of present-day northern Syria.

The materials unearthed indicate the crucial role held by Ebla large-scale interactions and exchange between Anatolia, Mesopotamia, Egypt, the Arabian Peninsula, the Mediterranean, and even further East as indicated by the raw lapis lazuli imported from Afghanistan. Later, in the final 3rd millennium BC (ca. 2300-2000 BC), the collapse of the city and its palace is not reflected in the settlement continuity of the sites scattered around the former capital.

The territory around Ebla is remarkable for the ecological diversity: limestone formations with red soils suitable for oil trees; basalt outcrops exploited as quarry for construction material; cultivation in flat marshland of the Matkh; the reliefs of the Jebel el-Hass and the Jebel Shbeyth. As documented in the cuneiform texts from the archive, the rich economy of Ebla was based on the integration of agriculture, breeding, textile production, trade, and even fishing into the Matkh.

The history of Ebla is therefore the history of a capital city and its close relationships with the surrounding territory. However, except for a few preliminary surveys carried out around Tell Mardikh during the late 60's and early 70's [3,4], the attention of the MAIS was entirely addressed to intra-site activities. A significant turning towards a "landscape perspective" has been possible thanks to the ERC-funded Ebla Chora Project – ECP (FP7-IDEAS no. 249394, 2010-2014 [5]), which made possible a first assessment of the archaeological landscape around Tell Mardikh/Ebla [6,7]. The main goal of the ECP was to understand the functioning mechanism of an early state and the relations of a Bronze Age capital with its surrounding territory. The ECP was conceived as a multidisciplinary project, where the archaeological data were combined for the first time with those from philology, geology, botany, agronomy, etc. in an attempt to consolidate and analyze comprehensively the mass of information collected in almost fifty years of archaeological campaigns. Nonetheless, the ECP occurred at the beginning of the Arab Spring in 2011, thus it was impacted by the civil war affecting Syria. Field activities planned over the four years were postponed and attention was diverted to a remote sensing-based assessment of the archaeological landscape [8] and the systematic study of the existent data acquired in previous decades.

3. From Ebla Chora to Big-DEA

Capitalizing on the results of the ECP, the Big-DEA project is based on an integrated multidisciplinary approach that combines multiple datasets (archaeological, philological, environmental) into a structured geospatial database that optimizes the search and analysis of a large amount of information. This large array of both published and unpublished materials are framed into a relational database management system functional to the implementation of the available GIS platform and the development of an appropriate simulation framework.

The challenge of the project is to obtain, for the first time:

- A quantified picture of the resources accumulated, redistributed, and mobilized by individuals and households, including the royal household and other members of the elite;
- Providing an estimation of resource exploitation, of ancient yields, agricultural land and livestock, of waged personnel and of population densities at Ebla and in village communities.

The exceptional information available offers a unique possibility to reconstruct, through a combined analysis of archaeological, paleoenvironmental, and textual datasets, the function of the economic and political core of the Ebla state. Moreover, the large array of data available from the northern Levant and Mesopotamia allows to broaden the picture and to explore the socio-economic landscape of Ebla and its territory.

4. Big Data and GIS

The project will benefit of the recent attention addressed to Big Data in archaeology [9–11]. Due to its trans-disciplinary nature, archaeology usually deals with data acquired in the long term (even decades), at different scale (regional to local), and from different fields/research groups, hence producing a large amount of information to be processed and analyzed. The volume of material produced during and after the several campaigns (1964-2010) at Tell Mardikh/Ebla allows considering it as a Big Data case.

The use of Big Data and their combination into a georeferenced framework will allow to investigate the structure of the Eblaite polity in between its emergence (2700-2450 BC), rise (2450-2300 BC), and demise (2300-2000 BC), through the detection of settlement patterns and socio-economic strategies at Ebla and in its region during the timespan considered. Major questions are therefore addressed to land use and resource exploitation, agricultural processes and animal breeding, interaction between settled farmers and nomad pastoralists, relationship between urban centers and rural villages, reconstruction of the structure of the households and their relationship with land and labor management (land tenure system, taxation/tribute, workforce).

Until recently, the reconstruction of 3rd millennium BC urbanization and archaic state formation mainly interested case studies from Mesopotamia [12]. The analysis and quantification of currently available data from archaeological and textual datasets from Ebla and its region will be used to make of this site a new frame of reference and comparison for the debate on archaic state formation in 3rd millennium BC northern Levant. Data from different fields will be integrated within a GIS framework and analyzed in a diachronic perspective and at different scales:

- An intra-site analysis focusing on Tell Mardikh/Ebla. The large number of cuneiform texts from the Royal Palace provides a homogenous amount of information on the management of economics in the Ebla state. A systematic approach, so far never attempted, to the quantifiers (numbers, units of measurement) and the quantified items (persons, animals, and goods) recorded in cuneiform texts can offer relevant improvements for the understanding of the activities of the various social agents operating in the territory under investigation, as well as the conditions of the environment in which they operated.
- A regional scale analysis, considering the data gathered from the administrative records, archaeological surveys and targeted excavations, and their integration with remote sensing, geomorphology, and agronomy;
- A wider geographical analysis of the interregional Ebla interaction's network, based on provenance of materials and objects, toponyms, commercial and diplomatic relationships, least-cost corridors, rank-size analysis, and natural routes. One of the main targets is the geographical definition of the Ebla region according to both the textual information and archaeological evidence [13], including inter-regional analysis based on the surveys and excavations carried out at the nearby sites of Tell Tuqan, Tell Mastuma, and Tell Afis [14].

5. Preliminary activities on geospatial data

The first step included an update assessment of the archaeological landscape of the region under investigation. The socio-political events of the last decade connected with internal crisis and ISIS occupation, resulted in severe damages to the cultural heritage of Syrian and other Near eastern countries [15–17]. As a consequence, many multilayered artificial mounds (locally known as *tell*) associated with pre-Classical settlements were interested by the excavation of trenches for military purposes, looting, construction of buildings, agriculture, etc. (Figure 1). The remote sensing-based evaluation evidenced how all the ca. 70 *tell* in this area were are altered by one or more of the activities mentioned above. This has considerable implications, such as the failure to protect an archaeological asset and, above all, the irreversible loss of information useful for the historical reconstruction of this territory.

Figure 1. Example of military trenches (left, Tell Zeytun EC-017) and looting (right, Tell Dadin EC-057).

The second step included the reappraisal of the material culture from the de Maigret's survey stored within the MAIS archive. This operation made possible an update chronological assessment of the pre-Classical *tell* around Ebla (Figure 2): the number of sites dated to the Early Bronze Age IVA (the period of the Royal archive) increased to 72 (+60%), while those of the Early Bronze Age IVB to 45 (+46%).
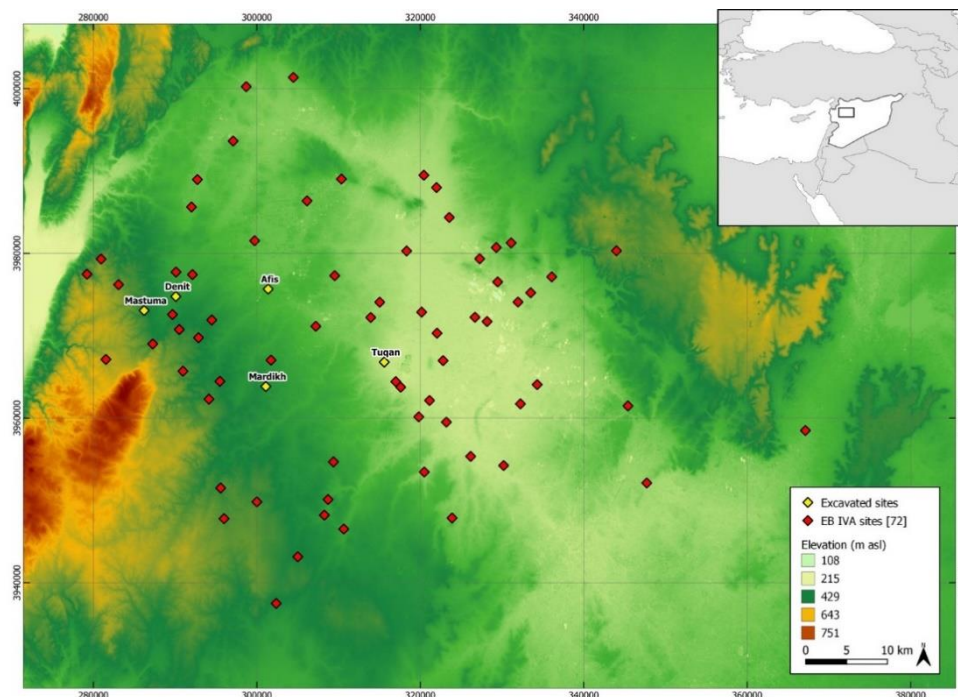

Figure 2. Early Bronze Age settlement pattern after the Big-DEA update.

A further step is the processing of historical datasets to obtain metrical information. An interesting case comes from the creation of a digital elevation model using declassified analog satellite images from the US reconnaissance program Hexagon (KH-9). The images are dated to the 1st August 1973, acquired at the height of 160 km with a ground resolution around 10 m. For the DEM extraction we used PCI Geomatica software, with a bundle adjustment approach, using about 30 ground control points available from the military French maps dated to the 40's, and 70 tie points, including crossroads, geodetic iron towers used by topographers on the field, etc. The result is a DEM with a 20 m resolution, which is better if compared to the 30 m usually available from free available elevation datasets like SRTM and ASTER GDEM. For the evaluation of the model, 55 further height points derived from the French maps were used, showing a certain underestimation of the elevation values, with a standard deviation of 8.6 m (Figure 3).
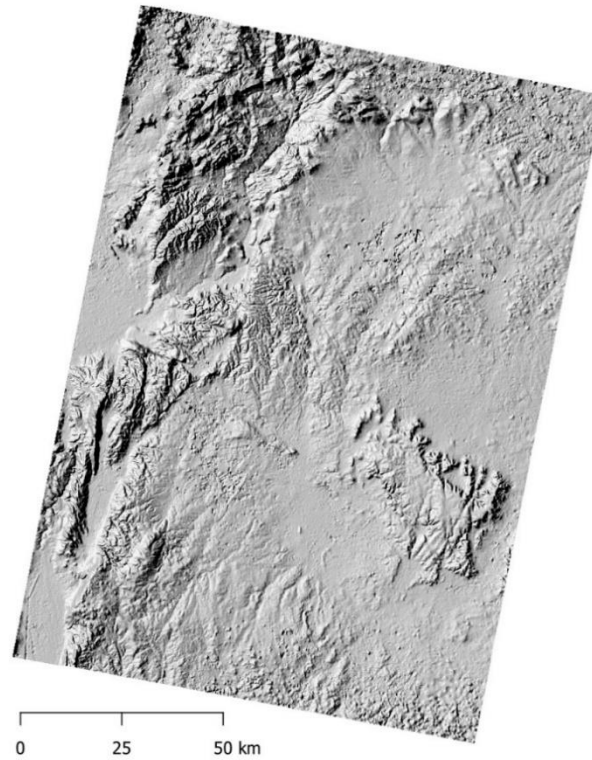
Figure 3. Hill-shading on the 3D model obtained by HEXAGON satellite images.

The characteristics of the DEMs obviously have implications on the products that can be derived from them: an interesting example is related to the least-coast path analyses performed between Tell Mardikh/Ebla and some sites selected in the territory at a different distance and ecological zone. The most remarkable case is the path connecting over on the long-distance (about 70 km) Tell Mardikh/Ebla with Tell Munbatah. The least-cost path generated over the ASTER GDEM (Figure 4, black line) passes through one other archaeological site only, while the least-cost path from the DEM processed on the HEXAGON (red line) passes in correspondence of all the archaeological sites (five) located on that route.
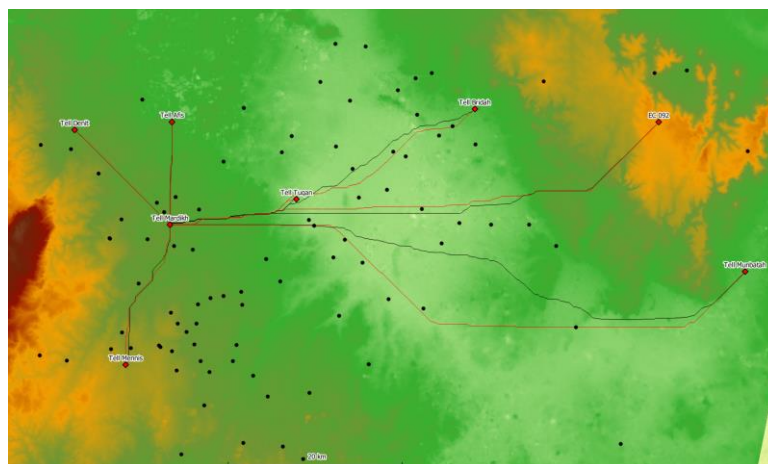

Figure 4.Least-cost path analysis performed on the ASTER GDEM and the DEM from HEXAGON.

6. Conclusion

Although at a very preliminary stage, Big-DEA provided a first update of the historical trajectories of an ancient capital city within its close surrounding territory. The possibility to combine archaeological, textual, and environmental information with high-resolution geospatial datasets makes possible to

analyze the diachronic and synchronic distribution of settlements according to their many characteristics (size), as well as in relation with the ecological variables of this region.

7. Acknowledgements

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