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Hydrological modeling and management of water resources in the Syrian steppe during the Early Bronze Age, the case of the fortified city of Al Rawda.

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Abstract

During the end of the third millennium, populations settled in the Syrian steppe amid the arid margins of the Fertile Crescent. The establishment of a series of settlements, often fortified, raises the question of how these settlements subsisted in an area of marked aridity.

An investigation planned over 5 years, centered around the sedentary site beginning at the end of the Early Bronze Age, Al Rawda, located in a fayda, is aimed to chart precisely the vestiges present in this pioneer territory. Initial results have made it possible to identify several hydro-agricultural installations. A geoarcheologic survey was initiated and coupled with a space analysis using GIS, which aims to specify the functionality of installations. The construction of a DEM using statements in mesh using a differential GPS Trimble Pro XRS made it possible to identify clearly, through detailed hydrological analysis, the hydrographic network as well as the contributive surfaces of the basin's slopes. Initial results show:

- Stock management of water was probably articulated around a hydraulic installation system, making it possible alternatively to use the flows available from the main wadi and those of its secondary tributaries. The hydraulic system, of which remains only a palimpsest, made it possible to optimise all flows available and to direct them, using a distributor, in a differentiated way towards zones of agriculture where water needs temporally varied.
- Stock management of water may have determined for a great part the structural organization of space around the site.

Lastly, one measurement made following an observation of a pluviometric event, by the intermediary of the DEM, allowed the quantification and subsequent modeling of the contributions of possible water and the measurement of various flooded surfaces.

Introduction

In the far eastern Syrian steppe, well below the 200 mm isohyet, sedentary populations established territories at the turn of the second millennium BC. This occupation was relatively brief – just a few centuries

– and the reasons for its existence are still unknown. We can however study the natural environment of this small region, and through the vestiges of this period attempt to understand how this occupation and organization established and existed.

The climate of the area is not favourable to agriculture. If it can be established that these populations were herders, their sedentary way of life would imply that they practised other modes of subsistence. It is

therefore necessary to study the local resources in terms of crop cultivation, which in this arid area would need a rudimentary form of irrigation.

Our investigation is organized on the study of environments with a geo-archaeological approach, closely linked to the archaeological evidence; the goal is to understand the manmade elements in their environmental context, in accordance with stratigraphic evidence. Another goal of the study is to clarify the horizontal relationships of proximity and distance of the vestiges of occupation. For this, all the field data – archaeological data and environmental data – are located with a differential GPS and recorded in a Geographic Information System (GIS). The GIS enables organisation of the inventories and production of multiple maps (Barge, Sanz, Mouraille in press). This tool enables us to analyse the main results of the survey. Results were acquired during the first two field seasons (2002 and 2003), each lasting two weeks. We will present the results of a spatial analysis, conducted with the GIS, a calculation of water flow lines, which will enable us to confirm the hypothesis of cultivation in immediate proximity to the town of al-Rawda.

Presentation of the study area

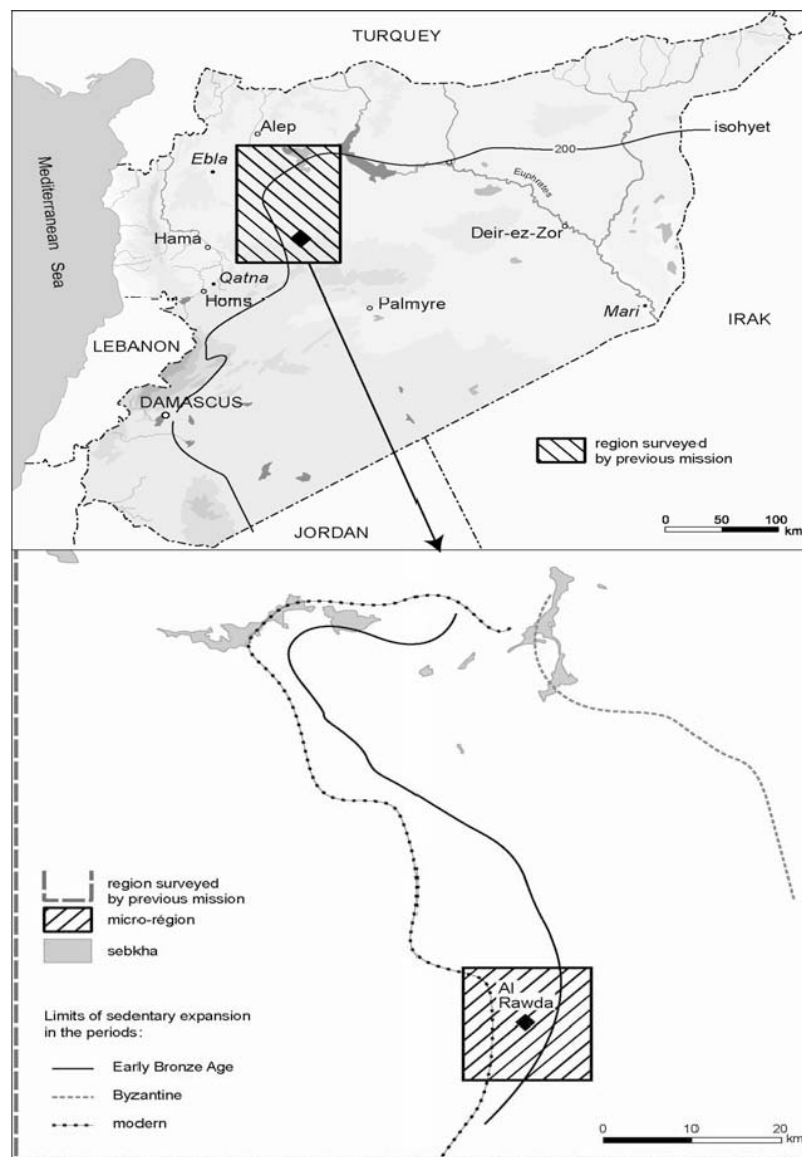


Fig. 1 - Location of the zone of study and the limits of sedentary occupation

This study benefits from the results of a much larger survey (10,000 km²), directed by Bernard Geyer between 1995 and 2002, which had as an objective an exhaustive inventory of archaeological sites for all periods. One of the important results of this research was the revelation of the ebb and flow of human populations in the region. The western part of the study area lies in the Fertile Crescent, which has been continuously occupied, whereas the arid eastern part has only been occupied by sedentary people periodically. This was the case at the end of the Early Bronze Age when these lands were first conquered (Geyer, Calvet 2001). The limits of sedentary occupation in the east (Fig. 1) were only exceeded in the Byzantine period; even today, semi-nomadic populations occupy the region only in winter. There are many Early Bronze Age sites, which densely occupied the territory; their eastern limits are marked by the Wadi al-Amur, which provides water to al-Rawda. The sub-region under study is thus a window of detailed investigations in the heart of the study zone of the previous survey, astride the edge of sedentary occupation defined by that survey (Fig. 1).

The recent excavations at al Rawda have shown that this is a fortified urban site, measuring some fifteen hectares of which 12 are intra muros, dating to the end of the Early Bronze Age (Castel, 2004). The Franco-Syrian archaeological survey, directed by Corinne Castel, delineated a sub-region of 100 km² centred on this site in order to study its territory. The region is not totally inhospitable, which is the case farther south and east, but has high aridity with very irregular precipitation (Jaubert, 1999). It is a marginal zone.

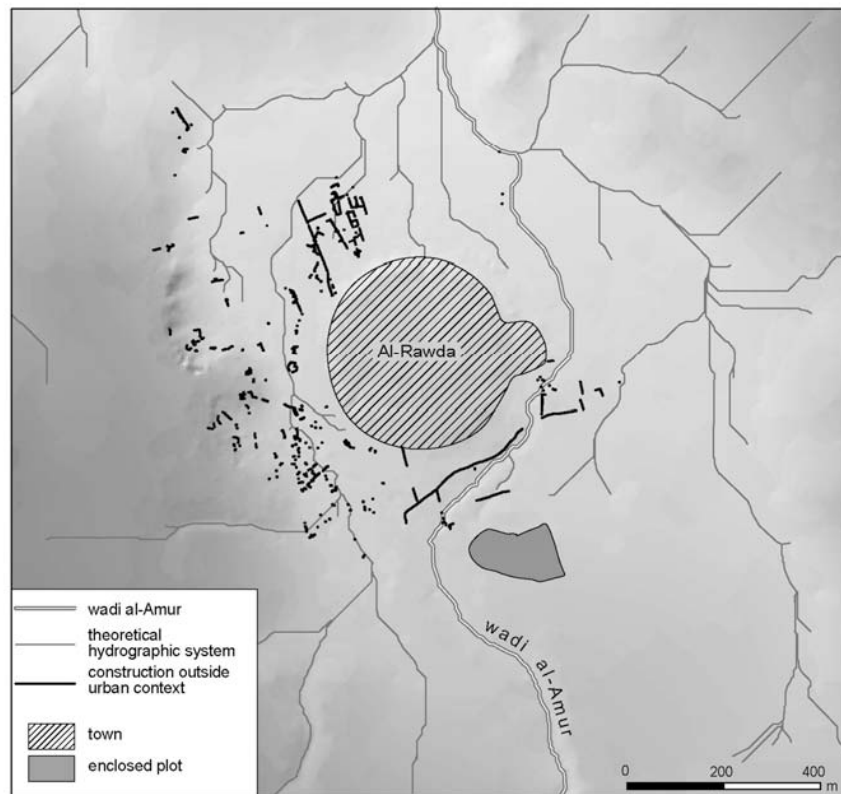


Fig. 2 - The fayda of al-Rawda and hydro-agricultural constructions

In the center of this sub-region lays the site of al-Rawda in a faydas. The faydas are alluvial depressions, where downstream channel narrowing has led to high sedimentation rates. The clayey-silty soils are deep, well drained and receive water from the wadis that cross them. Thus, these are favourable environments, which contrast strongly with the interfluves that are covered with a calcareous crust; dry environments where sparse vegetation grows on thin strips of soil.

Remnants of cultivation in the sub-region are few; dry farming remained difficult because of the high aridity, even in favourable environments such the valley beds or the faydas. Nevertheless, the archaeobotanical results obtained in stratigraphy on the site of al-Rawda (Herveux 2004) identified ruderal vegetation indicative of irrigation, as well as the cultivation of olives, vines and legumes, which strongly suggests there was at least minimal irrigation. Moreover, around the tell of al-Rawda, beyond the urban context, are a series of structures which are generally poorly preserved but whose general plan suggests an organized system of water flow (Fig. 2). Although visible on the ground, their presence and their organization were revealed from air photographs taken from a kite (Sanz, Barge in press).

The GIS have verified the hypothesis of the existence of relatively crude hydraulic constructions, enabling the use of natural water flows for agriculture, hydrographically.

Methodology

A Digital Elevation Model (DEM), a digital description of the relief where each pixel of the image carries an altitude value, was obtained by interpolation of points measured in the field using a differential GPS, over a 3 km x 3 km surface area centred on al-Rawda, with a regular grid of 100 m. In order to develop the DEM, we used a Trimble Differential GPS Pro XRS and a cross-country vehicle. The altitude point precision recorded using the DGPS is decimetric. Further, we used points provided by topographers using theodolites, which are reliable and adjacent to the site.

The more than 4000 topographic points recorded allowed for the calculation of a digital elevation model, or DEM, aided by the topogrid control mechanism in ArcInfo (ESRI). We used this DEM, to test our hydrological hypotheses.

Results and Discussion

Description of the presence of a system of river flows control and management :

An analysis of the theoretical water flows using the DEM delineates the present course of the Wadi al-Amur, which passes east of the tell of al-Rawda, as well as the small tributary wadis that originate locally (Fig 3a). Just upriver from the tell are partly destroyed structures, consisting of an in place dike as well as several adjoining walls. Some appear to have been longer, but their outline in the course of the wadi has been destroyed. One of these walls has been reconstituted virtually in the DEM. A new analysis of theoretical water flows shows a diversion of the main wadi towards the west of the tell (Fig. 3b). This structure could have been used to divert water when the stream swelled and conduct it right or left of the tell according to necessity, towards plots requiring water.

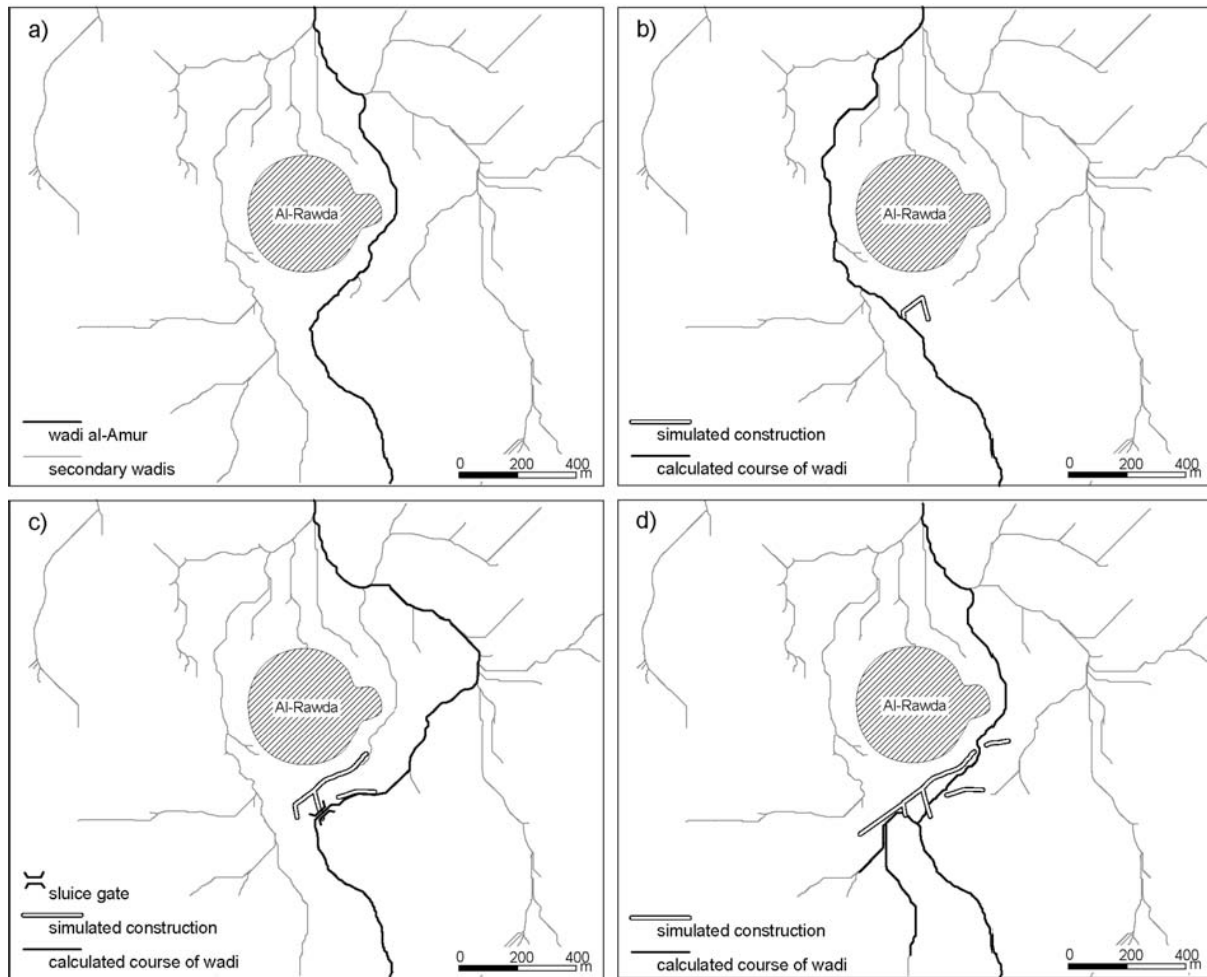


Fig. 3 - Theoretical water flows and simulations of hydraulic works

Similarly, a sluice gate was simulated in the structure, and a new diversion appeared. The water flows to a second dike in place, which allows flow to be directed to the easternmost part of the fayda (Fig. 3c).

Thus, there probably existed a hydro-agricultural system, of which there are only remnants but from which the main orientations can be detected. Moreover, the interfluvium between the Wadi al-Amur and a small tributary from the left bank ends with a low ridge, which adjoins the dike. It is possible given the low relief that the dike originally continued westward to harness the waters of this wadi (Fig. 3d). This structure would allow the exploitation of this water source; temporal water availability would increase as the two water courses may not have flow at the same time. The small wadi could flow as a result of a local rainstorm while the main wadi remained dry.

Estimate of water volume :

A rainfall event (18 mm) that occurred during the 2003 survey enabled the evaluation of the volumes that pass through this system from this tributary wadi (Fig. 4). The theoretical threshold of 10 % was retained to calculate the infiltration value.

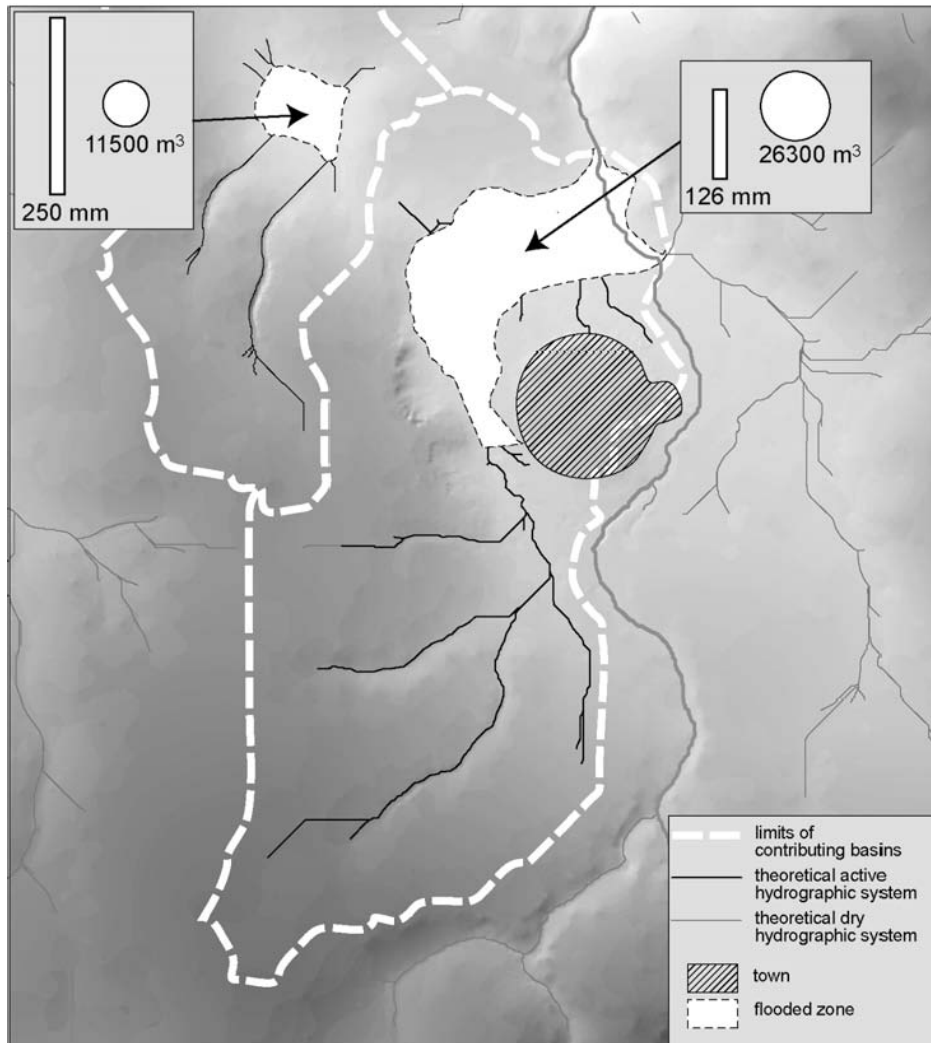


Fig. 4 - Calculation of the volumes of water infiltrated during the rainfall event of 3/10/2003

The use of a hydrological model enabled us to roughly calculate water volumes moving through this network. During the event more than 25,000 m³ infiltrated the western part of the fayda. On the flooded surface, this represents a 126 mm water layer; nearly equal the average annual rainfall.

The potential in terms of arable land of the fayda could have been captured by hydro-agricultural structures that enabled the exploitation of local water flows or those coming from the main wadi. The low relief of the area required only modest structures to utilize rainfall to the best advantage. The simulations correspond to earth embankments of no more than 80 cm. One can imagine that the fayda as a whole was adapted in a manner similar to that of the villagers in the 1950s: earth embankments set perpendicular to the flow accumulated the water and sediments behind them. We know that these techniques were known in this period, and similarly used near al-Rawda (Braemer, Echallier 1995).

Conclusion

There is strong evidence that a system of irrigation existed on the Al Rawda site. This system of clever gravitating irrigation was well adapted to the specific hydrological temporality at the fayda of Al Rawda junction.

Although the practice of irrigation agriculture has been revealed, it seems not to have extended beyond the immediate environs of the ancient town. At the end of the third field season, the survey was able to identify new indications of hydro-agricultural structures, but their function remains unclear. They usually affect only small surfaces, not necessarily associated with habitation sites, which is the case at al-Rawda. Two sectors with this type of construction situated in the fayda of Tarmaz in the Wadi Qastal are candidates for future study.

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