Broadening Horizons

Broadening Horizons
Multidisciplinary Approaches to Landscape Study

Edited by

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PREFACE

The process which gave rise to this book began in the spring of 2006, in the wake of the first ‘Broadening Horizons’ conference on multidisciplinary landscape study (Ghent, Belgium). At the time, we - a group of ‘mere’ doctoral students - were already happy enough to have pulled off the organisation of an international conference; the idea of having it flow over into a publication was probably the farthest from our mind as we were enjoying our well-earned closing dinner. But after the dust of those hectic final weeks had settled and the ideas put forward in the presentations had sunk in, we began to play with the idea nonetheless.

And so a year later, we are pleased to present this volume on behalf of all who contributed before, during and after the conference. We expressly opted to make the leap from a ‘conference proceedings’ to a stand-alone volume of selected essays, as we felt the latter would better lend itself to the distribution of the interdisciplinary and supra-regional scope that we deem an absolute necessity of landscape research. The selected texts as a result take diverse angles at tackling the ‘landscape problem’, covering ground from the Central Mediterranean to the Middle-East and from semi-automated remote sensing to cuneiform historical geography. By including contributions from beginning and more established researchers alike, we aimed to produce a volume of potential interest to both the student and the specialist. Aside from offering concrete examples of applied methodology, we hoped the book might through this intentionally broad gaze also help further interdisciplinary awareness.

Thanks go out firstly to the authors who contributed to this volume; we also regret that, given the preset publication size, not all papers which we received could be included. A special acknowledgement must be made to Prof. Tony Wilkinson, whose contribution to the conference and key-note lecture proved more stimulating than we could ever have hoped for and who has kindly agreed to write the introduction to this book. Finally, we thank our colleagues here at the university: Sarah Deprez, Joke Dewulf, Tanja Goethals and Wouter Gheyle; for their shared enthusiasm, hours of overtime and combined expertise which made Broadening Horizons possible.

Bart Ooghe and Geert Verhoeven

INTRODUCTION

TONY J. WILKINSON

The landscape is all around us, but because of its ubiquity and complexity it is necessary to harness a wide range of approaches and techniques if it is to be described and understood. Hence the sub-title of this volume underscores the multidisciplinary nature of landscape study. Although the landscape might be characterized as simply the physical landscape that has been progressively transformed by human agencies, it is more complex than this, because in its turn the landscape also frames and is indeed part of the human experience. That said, humans do not follow linear trajectories through time: they experience and worship, they trade and perish, they fight and farm, with the result that it is no easy task to frame a landscape study in a way that is satisfactory to all. As a result of such problems I sometimes yearn for a return to an archaeology that treats typologies of urns, socketed axes and spear heads.

On the positive side, many of the everyday human activities referred to above do leave a recognizable physical signature on the landscape in the form of archaeological features or geoarchaeological traces. A number of years ago Colin Renfrew remarked that every problem in archaeology starts off as a problem in geoarchaeology. This statement remains very true to this day, whether one is looking at the sequence of an excavated site, the distribution, sourcing and technology of artefacts, or the development of regional patterns of settlement. In fact landscape archaeology, which forms the subject of this volume, should necessarily include a component of geoarchaeology. The combination of geoarchaeology and landscape archaeology therefore provides an academic field of considerable scope and rigour, an approach that is followed by many of the papers in this volume. This of course is not novel, indeed fundamental pioneer studies were made by Karl Butzer (1971) and Claudio Vita-Finzi (1969) a generation ago, and earlier in the 20th century Ellsworth Huntingdon (1907) and Aurel Stein (1921) included a wide range of landscape and geological studies in their investigations of Central Asian archaeology. Nevertheless, the articles in this volume demonstrate that the field continues to evolve, develop and innovate, and an exciting feature of it is that several papers offer new techniques or approaches that have been developed only within the past few years.

'Broadening Horizons' showcases a range of landscape studies drawn from the Mediterranean and Near East backed up by field studies stretching geographically from southern Mesopotamia to the Central Mediterranean. The sub-title 'multidisciplinary approaches to landscape studies' might raise a note of concern, because in recent years 'landscape archaeology' (this was the most represented discipline in the original conference – *editorial note*) has become so broad that it has sometimes lost sight of its disciplinary core. However, by focussing on the recognizable signatures of human activity in the landscape, as well as elaborating relations between human movements, networks or industrial activities, this volume takes an approach that often successfully combines geoarchaeological techniques with the insights developed by the broader perspectives of the landscape archaeologist.

Although the techniques and subject matter of the contained papers are rather different – ranging from OSL dating of riverine sediments, remote sensing, the creative interrogation of cuneiform texts, soil analysis, and archaeological site survey – the volume avoids the trap of being so broad in its coverage that it loses thematic coherence. For example, several studies attempt to unravel some of the geoarchaeological data that lurks at the core of most landscape analysis. This approach is to be commended because when the term geoarchaeology was originally coined,[1] this sub-field of archaeology seemed to be quite remote from archaeology as a study of ancient society. Although we are now witnessing a narrowing of the gap between the two fields, it is necessary to be constantly vigilant to bring together both the physical and cultural analysis of landscapes.

In my keynote paper to the conference I argued that many features normally considered to be part of the cultural landscapes (roads, artefact scatters, fields and so on) in fact register in the landscape as a geoarchaeological signature, and that it is therefore imperative to examine landscapes from a geoarchaeological perspective. By way of illustration: fields contribute to the sediment load of rivers, or form extensive sediment traps that contribute either positively or negatively to what Walling (1996) has described as the 'sediment delivery problem'; roads conduct overland flow to become incipient channels that extend drainage density;[2] and archaeological sites become the resting place of materials

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[1] Davidson and Shackley, *Geoarchaeology*.
[2] Wilkinson, *Archaeological Landscapes of the Near East*.

such as food residues derived from their surrounding territories. One can even observe entire landscapes in which human action has wrought a geoarchaeological signature, in the form of highly 'eroded' quarry scapes as described by Heldal and colleagues in this volume. Several of the papers pursue what I would describe as 'landscape geoarchaeology', and many examine a range of human signatures and attempt to interpret them through the lens of the landscape via the techniques of geoarchaeology. As Lucke and colleagues describe, the use of geoarchaeology (and indeed pedology and geomorphology) as a way of exploring the dynamics of landscapes, enables one to side-step some of the one-way arguments that prevailed earlier in the 20th century, when humans were simplistically seen as contributing to wholesale landscape degradation. By describing the full complexity of the landscape, its soils and associated features, they provide a more nuanced and perhaps realistic analysis of processes of landscape transformation.

Topics covered in this volume include the recognition of tells and medieval sites by the use of remote sensing and field methods (Menze et al.; Saggiore), the examination of site territories and coastal communication networks (Fulminante, Storme et al., and Ivrou), the reconstruction of river systems using cuneiform texts (De Graef), the dating of their alluvial products (Deckers and Vandenberghe), 'quarryscapes' (Heldal et al.) and the long-term degradation of the land (Lucke et al.). All of these subjects fall within the general remit of landscape archaeology, and most also include a component of geoarchaeology either explicitly or implicitly.

Sadly, one of the named authors, Andrew Sherratt, did not live to see the fruits of this conference. For Andrew the landscape, frequently viewed through the medium of maps, was one of the fundamental components of archaeological analysis and in recent years his remarkably prolific 'Arch Atlas' web site has demonstrated just how the physical environment, trade and settlement could be brought together within one multi-facted web site. The pioneering paper by Menze, Muhl and Sherratt, which supplements earlier preliminary publications, demonstrates successfully how new technologies can be harnessed to actively map and record the landscape. This innovative method, developed as a collaborative venture, provides a fitting tribute to the memory of Andrew Sherratt.

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CHAPTER ONE

VIRTUAL SURVEY ON NORTH MESOPOTAMIAN TELL SITES BY MEANS OF SATELLITE REMOTE SENSING

BJÖRN H. MENZE, SIMONE MÜHL
AND ANDREW G. SHERRATT (†)

The role of virtual survey

The study of "tells" is a fundamental category of archaeological research to which several authors within this volume have made notable contributions. At present, most of our knowledge of the distribution of tells derives from ground survey. This paper is a progress-report on a project aimed at examining whether we can begin to detect them more or less at will, from the kinds of information which are becoming available to us from space, from data sources such as multi-spectral imagery, digital elevation models on a global scale, or high resolution scenes with wide spatial and temporal coverage. Since in many areas tells are disappearing rapidly under agricultural improvement schemes or the growth of modern settlements, and since the data collected from space are constantly improving in their resolution, it makes sense to elaborate methods for what we may reasonably call "virtual survey": From the settlement mounds we know, we can derive mathematical descriptions within the satellite remote sensed data, and then systematically search the Earth's surface for phenomena with similar properties. With luck, most of what turns up should indeed be prehistoric settlement mounds (rather than, for instance, piles of road-stone awaiting distribution). While only "ground-truthing" through a site visit can confirm this, we will present an approach to such a systematic evaluation of remotely sensed data in the following, in particular by relying on data of the SRTM digital elevation model. It is not a substitute for traditional methods, but may become a valuable supplement to them.

Tells are a specific form of settlement-choice,[1] occurring over a well-defined area, from eastern Hungary to northern India, in places where mudbricks were used for building. Tell-formation is also characteristic of specific social and historical circumstances, since it is a phenomenon of a particular period and closely related to the advent of urban settlement systems. In cases in which sites lasted over millennia – and especially in which they achieved urban status – their size can be very impressive. Therefore it is not surprising that such sites have been the object of intensive investigation for decades.

Unfortunately, even the locations of large and important tell sites occur in the archaeological literature with unknown reliability (accuracy) and precision. Indeed, it is not uncommon to find significantly different co-ordinates being given for the same site in different sources. Even when the suggested co-ordinates do not plot in the sea (as some of the entries in archaeological gazetteers have been known to do), we are seldom sure whether they are intended to give merely a generalised indication of position, or a precise location. Just providing accurate co-ordinates for some very well-known mounds is one useful contribution of the present work. However, these major sites are only prominent representatives of a whole distribution of settlement mounds, still visible in wide areas in the Near East.

The major desire to interrogate the landscape for potential tells is that we have no clear idea how representative our current distribution maps really are. Naturally, they represent the cumulative result of several kinds of survey, with differing intensity. But have these been deployed in such a way as to sample the total pattern in a representative way, or are they just arbitrary and involuntarily self-confirming visits to the same places over and over again? (This is a characteristic problem of distribution maps, summarised in the aphorism that “archaeological distribution maps are maps of the distribution of archaeologists”). Do archaeological distributions really stop at international borders, as they uncannily seem to do on certain maps? While we cannot answer this question for finds of archaeological material (for instance particular categories of artefacts), we nevertheless can begin to do so for physical phenomena such as hills of a certain size and shape. Thus, providing comprehensive overviews of both their *spatial and physical distributions*, together with an accurate estimate of the “cut-off point” beyond which the smaller ones cease to be recognisable by current methods, is the primary incentive for the present work.

[1] Rosenstock, Tells in Südwestasien und Südosteuropa.

So, how could this be achieved? In the following we will briefly review the remote sensing of tells (section 2) and will describe the (semi-) automatic tell detection strategy which allows the virtual survey, and present first quantitative results on the distributions of tells in northern Mesopotamia (section 3). Finally, we will evaluate both the results qualitatively in a detailed case study and illustrate how the virtual survey on the SRTM model can be extended easily by other means of remote sensing (section 4).

Remote sensing of settlement mounds

From a simple physical point of view, tells are features of 5 to 50 m in height, 50 to 500 m in diameter, and usually of conical shape. Also, they primarily consist of loam and mud-based materials. Both features might be used in the identification of tell sites.

High resolution satellite imagery allows the resolution of objects even on a scale of meters or less (e.g. SPOT 10 m, ICONOS 1 m). They provide information similar to standard aerial images and can often be interpreted without ground control. Providing views onto scenes of the 1960s, before much of the modern transformations took place,[2] declassified CORONA imagery is used to study ancient sites in the Near Eastern landscapes.[3] Tells can be *directly* identified in the images or can be identified *indirectly* from the structure of hollow ways. Multi-spectral imagery, e.g. LANDSAT or Aster data, are a standard tool in the classification of ground cover and soil types.[4] In the detection of settlement mounds they are potentially helpful to identify the often un-vegetated and eroding tell sites.[5]

Investigation of tells from a three dimensional perspective is provided by digital elevation models (DEM). At a resolution of 3-8 m, the stereo views of CORONA imagery also allow to generate highly resolved elevation models[6], but only with considerable effort and within limited regions. The potential usefulness of data from the Shuttle Radar Topography Mission (SRTM) in the search for tells was identified shortly after the data were released.[7] With uniform coverage at a global basis and a high spatial resolution, it provides for the first time an opportunity to observe topographic phenomena at the scale of tell

[2] Intensified agricultural activities, but also increasing industry and transport lead also to the destruction of ancient sites and landscape features shaped in antiquity.
[3] Kennedy, Declassified Satellite Photographs and Archaeology in the Middle East.
[4] Fowler, Satellite Remote Sensing and Archaeology.
[5] Altaweel, The Use of ASTER Satellite Imagery in Archaeological Contexts.
[6] Gheyle et al., Evaluating CORONA.
[7] Sherratt, Spotting Tells from Space.

settlements: representing well-defined anomalies in the flat lowland landscapes in which they are typically situated, these artificial mounds can be easily 'spotted' in this DEM. This elevation model also provides insights to landscape evolution in alluvial environments, which was recently discussed by C. Hritz and T.J. Wilkinson.[8]

A wide, supra-regional survey sets certain constraints on the data which is being used. First, the availability of the data is a relevant issue. While high resolution and complete coverage is so far only available from commercial suppliers, also the use of 'low cost' data products, such as CORONA or Aster, amounts to considerable sums, when surveying wide regions is desired. Second, a high degree of automation in the routine work is required, to relieve the operator in the processing of voluminous data and to obtain a high objectivity and reproducibility in the analysis. It is also a basic necessity in an complete analysis of complex information, i.e. high-dimensional multi-spectral imagery. While a detailed *spatial* analysis of monochrome scenes still lies beyond the means of current image processing, methods for a machine-based evaluation of this (multi-) *spectral* information are readily available.

Consequently, in this stage of our survey we restrict ourselves to Landsat ETM+ and SRTM data. The favoured reliance of CORONA and Aster data will be restricted to a regional case study, due to their limited availability, but also due to labour-intensive manual effort required in the preparation of the CORONA images when registering the scenes, and heterogeneous data quality of raw Aster data. Unfortunately, by itself, the spectral signature of known tells has so far proven too unspecific to serve as a diagnostic characteristic in an automated detection. Thus, our search for tell sites is primarily based on the processing of the DEM data, only with the *ancillary* use of the satellite imagery and other geo-referenced information.[9] The algorithm for the evaluation of local *elevation pattern,* tailored to the search of small conical mounds,[10] will be described in what follows.

[8] Hritz and Wilkinson, Recognition of ancient irrigation channels in Mesopotamia using digital terrain data.
[9] I.e. detailed military topographic charts where eye-catching features in the huge Mesopotamian plains are carefully mapped for orientation and tactical purposes offers a fertile source of additional material to be considered.
[10] Menze, Ur, and Sherratt, Detection of Ancient Settlement Mounds.

Automated tell detection

The SRTM data used in Menze et al.[11] is derived from a test area in the north of Mesopotamia (Figs. 1 and 2).[12] The upper Khabur catchment has a long settlement history, and witnessed the major expansion of nucleated settlements in the third millennium BC, a region which is still a focus of current research.[13] The basin is covered by six SRTM one-degree tiles (36° N to 38° N; 38° E to 41° E) at three arc-second resolution (90 m, Fig. 2, *top*). As part of ongoing archaeological investigation of this region, 133 sites with an indication of settlement activity had been identified within the tile 36° N, 38° E. The tell sites had been identified from CORONA images and several seasons of fieldwork associated with excavation projects.[14] These tells range from one to 60 ha in area and from less than 5 m to more than 50 m in height.

In order to keep this validated data as an independent test set in the comparison between archaeological ground survey and computer based DEM survey, a second data set was acquired for the training of the classification algorithm. For this purpose the remaining SRTM tiles of the Khabur were visually searched for presumed settlement mounds. By means of Landsat ETM+ images and topographic maps it proved possible to identify a further set of 184 settlement mounds.[15]

Within the DEM data, these mounds usually appear as small contrasting spots. Although the geographic region under study is a relatively flat plain, natural variation of the land surface exists on different scales, ranging from slowly varying slopes to steep canyon walls (Fig. 2, *top*). This variation is superimposed on the characteristic point-like pattern of the tells. Following techniques developed for face recognition (‘eigenface’ subspace filters), a classifier was trained from the second set of the 184 tells which discriminates between the typical spot pattern of a mound in the DEM and the variation in its

[11] Menze, Ur and Sherratt, Detection of Ancient Settlement Mounds, 321-327.

[12] When implementing a machine-based search algorithm, a reliable ground truth is highly relevant both in the design of the algorithm (“training”) and the critical assessment of its performance (“test”).

[13] Ur, Urbanism and Society in the Third Millennium Upper Khabur Basin.

[14] Ur, Settlement and Landscape in Northern Mesopotamia; Wilkinson, Archaeological Landscapes of the Near East.

[15] Soviet topographic maps, 1:100000, U.C. Berkeley map collection.

background.[16] Applied to new data, the classification algorithm is able to provide ranked lists of positions with decreasing *settlement mound probability*.

On the SRTM test tile[17], it is possible to detect 85 out of the 133 test sites at a threshold, which results in 327 false positives for the 600*1200 pixels of the test region (northern half of the test tile); most of the undetected sites were lower than 5 to 6 m in the DEM. False positives were mostly either due to natural elevations resembling tells in height and size, which occur frequently in the undulating slopes of Jabal Abd al-Aziz and Jabal Sinjar, or they were due to artefacts caused by the presence of water surfaces. Obviously the first of these error sources sets natural limits to the presented application.

Virtual survey

Overall, the algorithm is able to guide an investigator to elevations which are most probably tells, under objective criteria, high sensitivity and specificity. Nevertheless, other sources of (digital) information are available and necessary either to increase the confidence in positions proposed by the classifier, or to rule out obvious false positives. Topographic maps and Landsat imagery are primary sources of this information. Topographic maps reveal typical place-names (i.e. ‘Tell’, ‘Tall’, ‘Tepe’, ‘Höyük’) or in some regions even indicate a settlement mound with an appropriate symbol. Landsat, but also commercial satellite imagery such as Corona, Ikonos, Quickbird and Spot give a direct view onto sites and serve as the first component for their visual inspection,[18] e.g. in the exclusion of natural elevations in mountainous areas or simply to identify recent 'tell-like' elevations (such as the piles of road-stones mentioned above). At a resolution which is more than five times higher than the one of the SRTM, and in conjunction with information from maps or based on the prior knowledge of the human operator, it also enables the detection of tell sites which are either too small to be seen in the DEM or which are missed by the algorithm, as they for example do not have the typical elevation pattern as a tell in the Khabur.

Technically the proposed 'virtual survey' is organized as follows: The classifier marks positions which are above a predefined 'tell mound probability' within an SRTM patch (Fig. 8). By means of comparison with maps and satellite imagery, which cover the same area, a human expert is able to mark any of these positions which appear to him as probable tell sites. A subsequent tool allows to

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[16] Menze, Ur and Sherratt, Detection of Ancient Settlement Mounds; Menze, Virtual Survey.
[17] Menze, Ur and Sherratt, Detection of Ancient Settlement Mounds.
[18] Wilkinson, Archaeological Survey of the Tell Beydar Region.

study these sites in detail and to register any available information: names and further evidence from the map, position in the DEM (and thus the height), extensions in the satellite imagery. A final comparison against names and positions from the nearest known tell sites, as obtained from external data sets,[19] links the results of the virtual survey against real ground truth.

Survey results – northern Mesopotamia

So far, 60 one-degree SRTM tiles in the region between 33° E and 48° E and 34° N and 39° N have been surveyed (Fig. 1), comprising the territory of south-eastern Turkey, parts of northern Syria and Iraq, but also parts of Lebanon and Iran. In all, 2148 probable tell-sites were recorded.

To obtain the height of a mound, a plane was fit repeatedly to selected reference points in its surrounding. The elevation was assessed as the maximal difference between the surface of the mound and the plane. Elevations in the SRTM are quantities averaged over nearly one hectare; therefore the base-to-top height of the mounds might be somewhat higher in reality. The accuracy of this procedure was in the range of metres, depending on the size of the mound and the topography of its environment.[20] The observed heights range from less than one metre to more than 50 (Fig. 3). Small (or low) sites predominate in the distribution of the recorded mounds.[21] Although some of the mounds reach considerable heights – even at DEM resolution – the majority of the sites lies well below 15 m. The distribution peaks little above the detection limit of c. 5 m (SRTM data accuracy)[22], few mounds reach heights of over 40 m.

The spatial distribution of the recorded sites shows a high degree of regularity, a feature which can be observed both in the western and in the eastern region. A high number of the mounds lie on a hexagonal grid as expected under 'ideal' conditions. Alternatively, they line up along rivers or wadis. Such observations had been recognised for other regions earlier,[23] but can now be studied in more quantitative terms. When resolving the height analysis to spatial subregions (Fig. 2), two tendencies can be observed: first,

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[19] E.g. Hours, Atlas des sites du Proche Orient; Ur, Settlement and Landscape in Northern Mesopotamia, Rosenstock, Tells in Südwestasien und Südosteuropa; Lehmann, Bibliographie der archäologischen Fundstellen und Surveys in Syrien und Libanon.
[20] Menze, Ur and Sherratt, Detection of Ancient Settlement Mounds.
[21] The distribution of the recorded heights can be approximated by a gamma distribution with shape parameter 2.70 (+/- 0.08) and rate 0.29 (+/- 0.01).
[22] Menze, Ur and Sherratt, Detection of Ancient Settlement Mounds.
[23] E.g. Adams, Nissen, The Uruk Countryside, 19, Fig. 8.

mounds at the 'outward margin' of the fertile crescent, in the direct vicinity to the Antilebanon and the Tauros mountains, tend to be higher than mounds at the inward regions with less precipitation (Figs. 1 and 2). Second, a decrease in the number of minor sites can be observed from east to west (Fig. 3). While a test for significant differences reveals that the height distribution of sites above 10 m is identical in all three areas indicated in Fig. 1, the number of smaller mounds decreases significantly from east to west.[24]

It is observed that rank-size-distributions of settlement systems ('Zipf's law') fulfill characteristic rules.[25] When testing whether this relation also applies to the distribution of tell-settlement heights, it is observed that a strict linear relationship might hold on the upper tail of the distribution, but a linearity cannot be assumed on the full distribution of mound heights (Fig. 4). Summing the heights of all recorded 'tell-like' mounds on a spatial grid, one might be tempted to interpret the resulting map as a proxy to tell-specific settlement activity (Fig. 5). However, turning a distribution of *characteristic mounds* into a map of verified *settlement mounds* remains the objective of further work. A detailed analysis of further satellite imagery is one way to obtain a more reliable assessment of the sites.

Case study

The plain of Makhmur

In the following case study we concentrated on the area east of Ashur, the first capital of the Assyrian state, cult centre and seat of the highest god of the Assyrian pantheon, Ashur. The plain of Makhmur is located in the triangle framed by the upper Zab in the north, the Qara Chauq mountains in the west, the lower Zab in the south and the river Tigris in the west, belonging to the heartland of the Assyrian state (Figs. 1 and 6).

The region provides the interesting opportunity to show the relation between settlements, climate and dependence on the accessibility of water resources. The north-eastern part of this plain lies within the 200-250 mm precipitation belt, which forms the fluid border between the Fertile Crescent, where dry farming is possible,[26] and the Syro-Arabian steppe, where the western part strongly

[24] Wilcoxon rank test at 0.01% level.

[25] Gabaix and Ioannides, The Evolution of City Size Distributions; Nitsch, Zipf zipped; also see references therein.

[26] It is to keep in mind that these values underlie strong annual fluctuations (cf. Wirth, Agrargeographie des Irak, 19-20). Efficiency of dry farming in relation to socio-

depends on irrigation with water from the river Tigris. Huge irrigation projects dating back to the Middle-Assyrian, Neo-Assyrian, Parthian/Sasanian, but also Early Islamic periods can still be traced on the ground and are clearly visible on satellite images (Fig. 6).[27]

Amazingly little is known about this area. Although anciently important routes directly linking major centres like Ashur, Arba-'ilu (modern Arbil) or Arrapkha (modern Kirkuk) crossed the plain, only single sites had been investigated, most of them situated close to the Tigris.[28] Important work in the inland has been conducted by M.E.L. Mallowan and M. El-Amin who opened soundings at Kaula Kandal, Old Makhmur (Tall Ibrahim Bayis) and Tall Akrah showing the importance of this region,[29] but also by W. Bachmann who mapped and described sites he visited during his work at Ashur and Kar-Tukulti-Ninurta, posthumously published by R. Dittmann.[30] A screening of the western part with remote sensing methods has been conducted by M. Altaweel.[31] Due to this rather limited number of ground surveys, a "ground truth" in its classical meaning is hard to archive. Fortunately, another possibility is offered by the remains of ancient routes and ways itself which are traceable by means of air photography, satellite imagery, respectively satellite photography, and to some degree on the ground.[32]

Hollow ways or more descriptive linear swales are depressions in soft ground through prolonged usage for intersite and interregional traffic.

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economic, political and environmental developments had been pointed out by Wilkinson (Linear hollows in the Jazira, Upper Mesopotamia, 549).

[27] E.g. Altaweel, Land of Ashur, 108-120, 129-32; Wilkinson et al, Landscape and Settlement in the Neo-Assyrian Empire, 27-32.

[28] Like Tall Kushaf, Kar-Tukulti-Ninurta, Ashur or Tall al-Naml. The river and the area close to it is still a major route from north to south. Archaeologists and travellers of the 19th and early 20th century mainly focused on the huge capitals of the Neo-Assyrian Empire which flank the Tigris. The main route to Arbil and then to Kirkuk and Baghdad started in Mosul where Ninive could be visited along the way. So there was no incentive to cross the Makhmur plain, which was partly deserted and pasture of nomadic tribes, and hard to cross (cf. Andrae, Das wiedererstandene Assur, 275; Wirth, Agrargeographie des Irak, map F).

[29] El-Amin and Mallowan, Soundings in the Makhmur Plain: Part I, 145-153; Soundings in the Makhmur Plain: Part II, 55-68.

[30] Dittmann, Ruinenbeschreibungen der Machmur-Ebene aus dem Nachlaß von Walter Bachmann, 87-102, Fig. 1.

[31] Altaweel, The Land of Ashur.

[32] Ur, CORONA Satellite Photography and Ancient Road Networks, 104-106; Oates, Studies in the Ancient History of Northern Iraq, pl. 1a.

Furthermore they also had been used for reaching the fields in the surroundings of a site, the closest sphere of activities.[33] From the air these features are distinguishable from the soil by darker colour than the surrounding area. This is due to infillings of soil wash and continuous agricultural activity. Differences in vegetation,[34] resulting from a drainage effect can also be recognised at wadis which are filled by plough wash (Fig. 9). While on CORONA photographs they appear as lines distinguishable from the surrounding terrain by their dark colour,[35] additional multi-spectral ASTER images can complete the picture as they visualize hollows which are just apparent in the near infrared spectrum.[36] Ideally, these hollows allow to identify former settlement sites indirectly.

Especially radial hollows concentrating around central tell sites are interesting for verifying a tell-like mound of the DEM. Critical voices could argue that not every site or tell site shows linear hollows in its proximity. This might be due to 'short term' occupation, lower population density and little agricultural activities (in comparison with the larger Bronze Age centres), soil erosion through recently intensified agriculture possible by making use of fuel pumps for intensified field irrigation, and of modern harvesting machines. However, this will primarily affect very small tell settlements and low mounded sites, not visible in the DEM, and the presence of linear hollows in the vicininty of tell-like elevations still remains a positive indicator of a settlement mound.

Mounds in the DEM

Compared to the upper Jazira, which is known for its high number of tell settlements, the concentration of sites visible in the DEM is relatively low. Most of them can either be found in the centre or in the southern part of the plain (Fig. 8). Some examples of those sites shall be discussed in the following.

Out of these, the biggest settlement mound (in the means of the height of its debris in relation to its probable outline)[37] spotted by the classifier is Tall Akrah

[33] Wilkinson and Tucker, Settlement Development in the North Jazira, Iraq; Wilkinson, Linear hollows in the Jazira, Upper Mesopotamia; for a brief introduction of the investigation and interpretation of hollow ways in the Near East see Ur, CORONA Satellite Photography and Ancient Road Networks, 102-104.
[34] For example obvious differences of heights of the natural cover or grain (see Oates Studies in the Ancient History of Northern Iraq, pl. 1a).
[35] Ur, CORONA Satellite Photography and Ancient Road Networks, 106.
[36] Altaweel, The Use of ASTER Satellite Imagery in Archaeological Contexts, 153-157.
[37] Altaweel, Land of Ashur, 164.

which is supposed to be the Old-Assyrian *Ekallatum*[38] (Fig. 7, no. 1). On CORONA images, the radial hollow lines centred around Akrah (white arrows), are clearly visible, as well as a bigger hollow (black arrows) leading from the eastern bank of the Tigris opposite to Ashur straight to a col through the southern Qara Chauq in the east.[39] The circular shape of this site and its sharp slope within a plain terrain, features typical for tells in the upper Jazira, offers ideal conditions for the automated screening. Tall Aswad (Fig. 10 and Fig 6, no. 2): 16.5 km south east of Tall Akrah, is also characterised by its round shape and a hard slope. Just a few traces of radial hollows coming from north and from west (Fig. 10, no. 2) are visible on CORONA image. Tulul al-Nawwar (Fig. 11, Fig. 6, no. 3) is a site consisting of two elevated spots. Four radially hollow lines are traceable. One coming from the south-east might links this site with another one which could have been occupied during a time span when al-Nawwar was also inhabited. Complex sites like MKH0050 (Fig. 6, no. 4) consisting of a group of mounds which are positioned close to each other, appearing as an unified elevated structure in the SRTM model. Nevertheless, this "unified" mound, as well as all mounds described above, were reliably detected in the DEM by the "tell spotting algorithm" and could easily be identified as tells when checking the proposed sites with maps and LANDSAT data.

A high number of false positive hits are present in the northern part of the Makhmur plain, in vicinity to Qara Chauq. Here the lower quality of the data, but also the natural topography which is dominated by distorting wadis (Fig. 8) yields a variation of the DEM which results in a high number of erroneously proposed sites, prohibiting a reliable analysis of results from the automated screening, although tell sites are known in this part of the Makhmur.[40]

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[38] Dittmann, Ruinenbeschreibungen der Machmur-Ebene aus dem Nachlaß von Walter Bachmann, 100-102.

[39] This longer distance road would strengthen the identification of Tall Akrah with *Ekallatum* which is known to have lain close to a royal road *hūr šarri* (Schoeder, Keilschrifttexte aus Assur verschiedenen Inhalts, VAT 9658 (+) VAT 9626: 9; Kataja and Whiting, SAA XII 1:9); to 'royal roads' see Kessler, 'Royal Roads' and other Questions of the Neo-Assyrian Communication System, 129-136; Altaweel, The Roads of Ashur and Niniveh, 222, 224-225.

[40] For example Tell Kushaf at the estuary of the Upper Zab to the Tigris or Tell Ibrahim Bayis at the Husain al-Ghazi pass leading through the Qara Choq (Sarre and Herzfeld, Archäologische Reise im Euphrat- und Tigris-Gebiet, 210-212; El-Amin and Mallowan, Soundings in the Makhmur Plain 2, 55-60).

Discussion

The proposed survey on the SRTM model allows one to spot a high number of sites on a supra-regional scale. According to supplemental information of Landsat imagery and topographic maps, the recorded sites are likely to represent artificial mounds of characteristic tell-like shape. Mapping the mounds together with relevant physical parameters, such as height in the present step, spatial extension in a next, represents the major contribution of the proposed "virtual survey".

The survey has, so far, been applied to the plains of northern Mesopotamia. Limits arise both from the natural topography and the data quality. With a horizontal resolution of 90 m and a (relative) vertical accuracy of about five metres, it was only possible to reliably detect sites above these limits. While in the northern planes also a considerable number of mounds could be identified which did not surpass a height of 5 m in the DEM, but stood clearly from the surrounding area, the quality of the data deteriorated towards the south yielding a "rough" SRTM surface model, resulting in a high number of false positive hits (Fig. 8). The presence of geologic features resembling settlement mounds in height and size (in the DEM) also limited the usefulness of the SRTM in some regions. As a result, our survey is so far limited to north Mesopotamian plains and adjacent landscapes, where the link between tell-like elevation and real settlement mound might be allowed with the highest probability.

Overall, decisions about the presence of a *tell-like* elevation remain subjective to some degree. Thus, a more systematic evaluation of other sources of information is indicated to ease this decision and to increase the quality of the maps of the recorded mounds (e.g. Figs. 1 and 2). Besides the demonstrated usefulness of a detailed but time-consuming interpretation of CORONA imagery, it is the analysis of spectral data which, differently from mono-colour images, provides patterns which potentially are also interpretable in an automated, computer-assisted fashion. Although spectral imagery has proven to be an unreliable source in a rather global search over wide areas so far, it might yield valuable information on the local evaluation of a site in a further extension of the "virtual survey".

A final ground truth can only be obtained by real ground control. Linking the recorded co-ordinates with known sites and published information remains the ultimate step to verifying the mounds and to obtaining a temporal dimension for distribution maps as in figures 1, 2 and 5. However, the present results already allow the opportunity for further analysis, such as a study of the the spatial point pattern of the identified mounds or their correlation with other (geo-) physical parameters such as distance to river systems, precipitation, soil characteristics, to name just a few. The supra-regional data set resulting from the survey on the SRTM model might also serve as basis for either predictive[41] or generative[42] modelling approaches.

Conclusions

It has been demonstrated how the globally available SRTM elevation model can be used for archaeological remote sensing of wide areas. This considerably extends the current application of satellite imagery in restricted survey regions.

In general, we envisage a program of archaeological "virtual survey" for settlement mounds over a large part of the Near East, making use of a combination of automated and quantitative methods which are indispensable in a systematic screening of large amounts of complex data. The present work offers a methodology which increases our ability to screen for relevant sites, and to detect and evaluate rapidly and objectively any tell-sized mound within the SRTM elevation model. Further extensions of the survey to other parts of the Fertile Crescent not so far systematically subjected to ground-survey will incorporate new forms of analysis of multi-spectral data where necessary to overcome limitations associated with the particular topography and data quality of specific regions.

This ability to "virtually survey" tell sites over a huge geographical area provides unprecedented opportunities to uncover an enormous amount of information about the early history of human habitation in tell-building areas on a uniformly detailed scale. When calibrated chronologically it has the potential to tell us much about the formation and evolution of settlement patterns and the growth and reconfiguration of urban systems in a crucial part of the Old World.

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[41] e.g. Brand, Groenewoudt and Kvamme. An Experiment in Archaeological Site Location; or: Mehrer and Wescott, GIS and Archaeological Site Location Modeling
[42] Manrubia and Z Manrubia and Zanette, Intermittency model for urban development, and references therein.

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