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Preliminary ethnoarchaeological research on modern animal husbandry in Bestansur, Iraqi Kurdistan: Integrating animal, plant and environmental data

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This paper presents preliminary results from an ethnoarchaeological study of animal husbandry in the modern village of Bestansur, situated in the lower Zagros Mountains of Iraqi Kurdistan. This research explores how modern families use and manage their livestock within the local landscape and identifies traces of this use. The aim is to provide the groundwork for future archaeological investigations focusing on the nearby Neolithic site of Bestansur. This is based on the premise that modern behaviours can suggest testable patterns for past practices within the same functional and ecological domains. Semi-structured interviews conducted with villagers from several households provided large amounts of information on modern behaviours that helped direct data collection, and which also illustrate notable shifts in practices and use of the local landscape over time. Strontium isotope analysis of modern plant material demonstrates that a measurable variation exists between the alluvial floodplain and the lower foothills, while analysis of modern dung samples shows clear variation between sheep/goat and cow dung, in terms of numbers of faecal spherulites. These results are specific to the local environment of Bestansur and can be used for evaluating and contextualising archaeological evidence as well as providing modern reference material for comparative purposes.

Keywords: Ethnoarchaeology, Animal husbandry, Farming, Stable isotope analysis, Herbivore dung, Iraqi Kurdistan

Introduction

Ethnoarchaeological research has increasingly played an important role in the understanding and interpretation of archaeological deposits (see David and Kramer 2001: 1–32). This paper examines the modern rural village of Bestansur in the foothills of the Zagros Mountains, Iraqi Kurdistan (Fig. 1). This ethnographic research has been developed in the context of our excavations at the Early Neolithic site of Bestansur, located beside the modern village, and aims to contribute to archaeological analyses within the framework of the Central Zagros Archaeological Project (http://www.czap.org).

The purpose of this study is to elucidate aspects of the rural society and economy and how these function in the landscape and environment surrounding the village. Understanding the interplay of the varying environmental factors at a local and regional level, and their influences on animal husbandry (e.g. Bendrey 2011) and arable farming practices (e.g. Dreslerová *et al.* 2013) are essential for developing understanding of animal and plant use and economies at archaeological sites.

This programme of ethnoarchaeological research integrates closely with our ongoing research on mapping modern landscape isotopic and ecological variables (Bendrey *et al.* 2013). Modern behaviours can suggest testable patterns for past practices within the same topographical and ecological contexts (e.g. seasonal use of different altitudes for animal grazing), and if these areas are distinguishable by analyses of the modern biosphere, we may then be able to infer past use of these areas from isotopic analysis of archaeological finds (e.g. enamel in animal teeth formed at different seasons Bendrey *et al.* in press, Balasse *et al.* 2002b). It is essential to understand the full social and environmental context for integrated farming systems, to explore the

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Figure 1 Location of the study area.

drivers behind mobility, such as how mobile herding practices may be associated with differing local resource pressures.

This research aims to

- Understand how modern families use and manage their livestock within the local landscape (seasonally/geographically) and elucidate links between animal and plant resources that are an essential consideration for the elaboration of early Neolithic practices and the emergence of farming communities (e.g. Bogaard 2005; Henton 2012).
- Explore signatures left behind by the occupations and activities of this rural community (e.g. dung and local stable isotope ecology) that can potentially be identified as archaeological signatures on Neolithic sites such as Bestansur.
- Link the rural community to the physicality of the landscape, seasonality, climate and the overall context of the village, and evaluate constraints of the local environment on modern plant and animal husbandry.

In addition to addressing the need to explore signatures that may represent specific behaviours, which could be recognised archaeologically, our research strategy involves the creation of comparative datasets for which there is a requirement and demand (Lancelotti and Madella 2012). Creating our comparative datasets involves modern study of the use of plants and dung and to investigate spatial patterns of animal husbandry through isotopic analysis.

Study Area

Iraqi Kurdistan has a semi-arid climate with a strong continental component, characterised by cold and snowy winters and long, warm and dry summers (Table 1) (Maran and Stevanovic 2009). Normally there is no rainfall between June and September. Variation in the topography of Iraqi Kurdistan significantly influences rainfall distribution, with precipitation rates decreasing from the mountains of the north-east to the desert-steppe of the south-west (Maran and Stevanovic 2009: 21–22). The significance of water availability on pastoral and arable farming is not just a question of the quantity of precipitation, but also evaporation rates, amongst other variables (Lioubimtseva and Henebry 2009; Bendrey 2011). Table 1 presents average temperature, evaporation rate and rainfall for the region.

The modern settlement of Bestansur is a rural farming village of approximately 50 households, located at *c.*550 m above sea level and *c.*700 m from the archaeological site (Fig. 2). The environment

Table 1 Seasonal variation in the climate of Iraqi Kurdistan

	Average air temperature (°C) for Erbil (1959–1972)*	Average evaporation rates (mm/day) for Erbil (1966–1973)*	Annual monthly percentage distribution of rainfall (1941–1975)**
January	7·1	1·9	17·5
February	8·3	2·8	16·8
March	12·1	3·9	17·5
April	16·3	6·0	13·8
May	22·7	9·5	6·7
June	28·2	13·5	0·0
July	31·8	16·0	0·0
August	31·6	14·8	0·0
September	27·5	10·6	0·0
October	21·7	5·9	1·9
November	14·9	3·3	9·9
December	8·9	2·1	15·9

Notes:
*Data Erbil from Haddad *et al.* (1975) cited in Maran and Stevanovic (2009).
**Typical data for the annual distribution of rainfall in Iraqi Kurdistan, no location given (Maran and Stevanovic 2009: 24).

around the village of Bestansur can be split into different ecological and functional domains (Bendrey *et al.* 2012) (Figs. 2 to 5). There are three distinct physical zones around Bestansur: the river catchment area, the farmed alluvial plains and the limestone foothills (Figs. 3 to 5, respectively). There is one main water source in the village, a large karst aquifer (Saed Ali 2008) located directly below the village (Fig. 2). Impermeable beds around Bestansur prevent groundwater from percolating deeper (Saed Ali 2008), resulting in a substantial water source for the people of Bestansur.

Archaeological excavations at Bestansur are investigating a Neolithic phase of activity at the site (http://www.czap.org). These deposits at Bestansur represent an Early Neolithic settlement, with rectilinear pise architecture, which is located within the river catchment area. The research presented in this paper is aimed at providing the groundwork for ongoing archaeological investigations at the site.

The geology of the area is characterised by Cretaceous bedrock overlain by Quaternary alluviation in the area, which supports modern arable farming (Saed Ali 2008). Beds of sandstone or siltstone are inter-bedded with shale, marl or marly limestone being characterised by Cretaceous age rocks such as pelagic limestone and clastic rocks (Saed Ali 2008). The land around Bestansur consists principally of a gently sloping agricultural plain which now makes up the main cultivation land in this area, with the surface of the landscape composed of slightly undulating thick alluvial sediments recharged mainly by the direct infiltration of rainfall (Saed Ali 2008). Saed Ali (2008) identifies slight differences in age between the geology of the foothills and that of the alluvial Shaharizor Plain where Bestansur is located.

Research Context

Extensive ethnographic research has previously been carried out in the Zagros region of central western

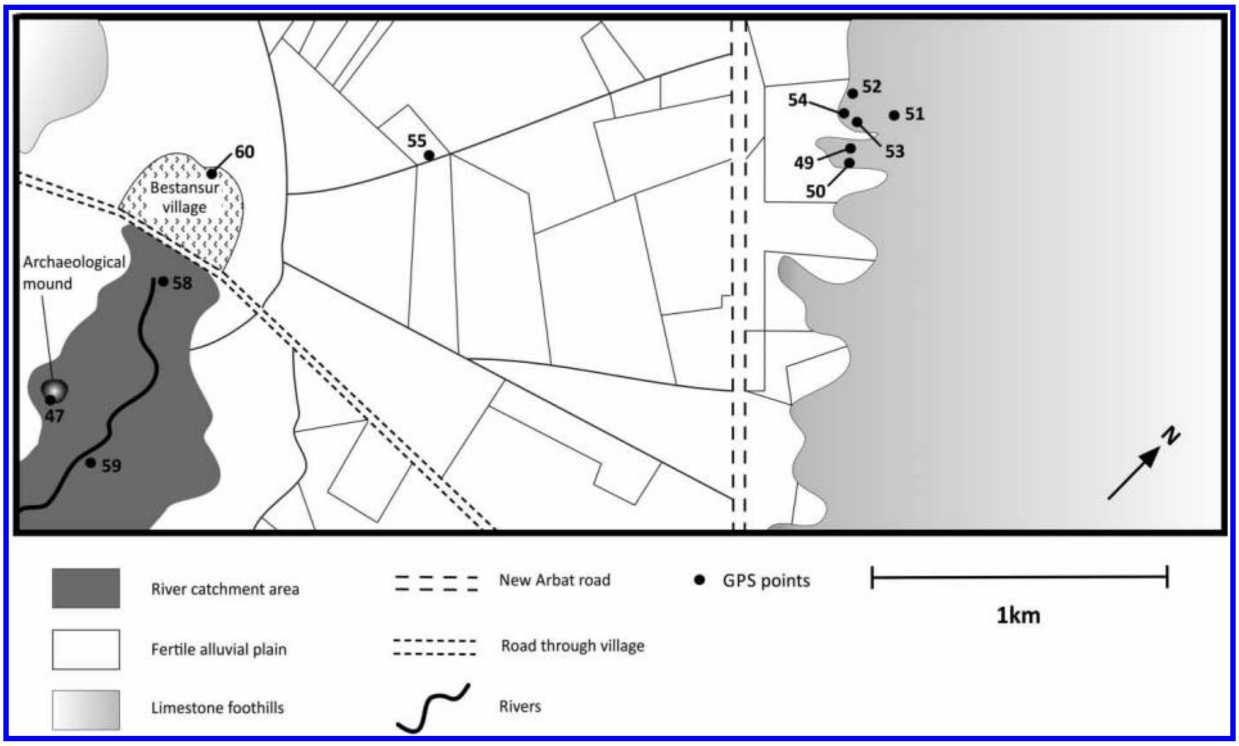


Figure 2 A simplified map of the local landscape around the modern village and archaeological mound of Bestansur, Iraqi Kurdistan. GPS Points: Plant, soil and water sample locations from the river catchment area, farmed alluvial plains and limestone foothills (referenced in text).

Figure 3 A goat herd daily grazing near to the archaeological mound in the river catchment area, Bestansur, Iraqi Kurdistan, spring 2012.

Figure 4 Sheep and goats daily grazing in fallow fields, on the alluvial flood plain Bestansur, Iraqi Kurdistan, summer 2012.

Iran during the 1970s and early 1980s. Studies focused on pastoral nomadism and transhumant stockbreeding groups (Hole 1978); economy, household size and village/domestic architecture (Kramer 1979, 1982); technology, the functions of artefacts and the nature of particular techniques (Watson 1979); and the correlation of the village with the land/environment, animals and plants (Kramer 1982). Limitations in extrapolating ethnographic observations to archaeological inference have been widely discussed (London 2000; David and Kramer 2001; Hamilakis and Anagnostoppoulos 2009). The

Figure 5 View towards the limestone Zagros foothills, looking northeast, from the village of Bestansur.

ethnoarchaeological approach we follow is more archaeologically orientated, generating hypotheses from modern-day research that can be tested with archaeological datasets.

Linking Ethnography to Past Landscape and Resource Use

There is significant debate as to the expression of practices of mobility in the archaeological past. Research has been hampered by the fact that mobile groups often leave behind only ephemeral traces (Cribb 1991). Within the Near East, recent research by Porter argues for a re-positioning of our ideas on the degree of mobility of populations and that archaeological models be based more on the evidence than assumptions. We address this by considering the availability of geographically and seasonally discrete resources in the landscape around modern-day Bestansur, interviewing local families to understand current and recent patterns of land use (especially involving livestock movement), which will ultimately link in with knowledge on the full range of mobile subsistence practices in the region, from sedentary farming through to fully mobile pastoralism (e.g. Hole 1978; Gilbert 1983; Abdi 2003; Porter 2012).

In recent years, it has become possible to directly test assumed patterns of archaeological mobility for past populations, through analysis of the isotopic composition of preserved skeletal tissues that can be used as proxies for understanding geographical origins and movements of the individuals concerned (Balasse *et al.* 2002a; Mashkour *et al.* 2005; Bendrey *et al.* in press). A range of researchers have used studies of stable isotopes in archaeological specimens to explore questions of the ecology, management and dietary history of prehistoric animals, including analysis of oxygen isotope ($\delta^{18}O$) composition from sequential enamel samples to investigate birth seasonality in past animal populations (Balasse and Tresset 2007; Britton *et al.* 2009; Henton *et al.* 2010; Blaise and Balasse 2011; Henton 2012), which can be used to infer past herd management strategies and seasonal availability of food resources (e.g. Balasse *et al.* 2003). Linking data on strontium isotope ratios to the seasonal sequence identified from the $\delta^{18}O$ values allows assessment of seasonal movement of the animal in relation to underlying geology (Balasse *et al.* 2002b; Evans *et al.* 2006; Britton *et al.* 2009). This has been undertaken to great effect in an ongoing project in the Altai Mountains, Mongolia, where local variation in geology and regional variation in oxygen isotope composition is providing detailed understanding of geographic origins and movements of animals, and the territories and migrations of the Iron Age pastoral nomads (Bendrey *et al.* in press).

Part of the study presented here involves isotopically mapping the local landscape to investigate potential variation in local biosphere values (Bendrey *et al.* 2012). It is envisaged this will form the basis for a control ‘map’ of the local region on which to test landscape-movement models generated by the ethnographic data. Ultimately, the aim is to analyse archaeological specimens from Bestansur and compare their isotopic compositions with these modern data, providing the

Table 2 Key ethnographic and experimental dung research by theme with references

Ethnographic and experimental dung research	References
Dung burning/fuel/ash	Watson (1979), Reddy (1999), Shahack-Gross *et al.* (2004, 2005), Lancelotti and Madella (2012), Portillo *et al.* (2014)
Sediments distinctive of livestock enclosures	Shahack-Gross *et al.* (2003, 2004), Macphail *et al.* (2004), Shahack-Gross and Finkelstein (2008)
Modern Pastoral sites	Shahack-Gross *et al.* (2003), Shahack-Gross and Finkelstein (2008)
Identification of dung	Shahack-Gross and Finkelstein (2008), Lancelotti and Madella (2012)
Modern diet, foddering or grazing	Watson (1979), Portillo *et al.* (2014)
Preservation of plant remains	Valamoti (2013), Wallace and Charles (2013)
Phytolith assemblages in modern dung	Shahack-Gross *et al.* (2003), Shahack-Gross and Finkelstein (2008), Portillo *et al.* (2014)
Chemical analysis	Lancelotti and Madella (2012)
Dung manure/fertilizer	Forbes (2012), Varisco (2012)

framework to make inferences on past mobility and resource use in the local landscape.

Dung is a major signature of occupation and activity that is also explored in this study. To date ethnographic and experimental modern animal dung studies are limited, and where they exist these datasets are often small (Table 2). However, reference collections and comparative data from different types of animal dung are increasing. The small datasets which currently exist have provided important comparative information for archaeological studies (Lancelotti and Madella 2012; Portillo *et al.* 2012, 2014).

Archaeological studies of animal dung are increasingly common although there is no standardised criteria for identification and analysis, numerous methods are currently employed (Shahack-Gross 2011: 206). Livestock dung at archaeological sites has been studied since the 1980s (Table 3) and research concerning animal dung, its recognition, contents, use and survival are increasing. It is now widely recognised how useful the study of animal dung is as an archaeological resource (Table 3).

Phosphorus has long been regarded as a good indicator of human activity (Middleton and Price 1996), and elevated phosphorus is usually considered to be the principle indicator of the presence of dung in archaeological samples (Holliday and Gartner 2007; Lancelotti and Madella 2012). Phosphorus enters the soil through decomposition of organic materials and waste (Parnell *et al.* 2001; Holliday 2004; Roos and Nolan 2012). Organic matter deposited into sediments decomposes and organic phosphorus becomes ‘fixed’ relative to other ions and is absorbed onto surfaces of clay minerals or bound to iron, aluminium or calcium to form Fe-, Al or Ca-phosphate minerals (Holliday and Gartner 2007; Roos and Nolan 2012).

A recent study has shown that the application of portable X-ray fluorescence (pXRF) analysis in the field (rather than in laboratory conditions) is remarkably low at only 18% of 200 peer reviewed papers (Frahm and Doonan 2013). There is extensive ongoing debate about the accuracy and precision of handheld XRF devices and their successful application to archaeological contexts with significant

Table 3 Key archaeological dung research by theme with references

Archaeological dung research	References
Studying the formation histories of the dung deposits and their archaeological identification and significance	Macphail and Goldberg (1985), Canti (1998), Canti (1999), Matthews (2008), Portillo *et al.* (2010), Shahack-Gross (2011), Lancelotti and Madella (2012), Portillo *et al.* (2012)
Identification of animal dung and animal penning/stabling	Matthews *et al.* (1997), Zimmermann (1999), Matthews (2005), Shahack-Gross *et al.* (2005), Albert *et al.* (2008), Portillo *et al.* (2009)
Dung deposits in rock shelters and caves	Wattez *et al.* (1990), Macphail *et al.* (1997), Rosen *et al.* (2005)
Specific grazing and foddering regimes	Halstead and Tierney (1998), Portillo *et al.* (2010)
Animal diet – charred seeds extracted from dung	Miller and Smart (1984), Miller (1996)
Animal diet – phytoliths extracted from dung	Powers *et al.* (1989), Shahack-Gross *et al.* (2003), Shahack-Gross *et al.* (2005), Albert *et al.* (2008), Portillo *et al.* (2012), Portillo *et al.* (2014)
Dung-derived plant remains – survival of plants in dung	Charles (1998), Charles *et al.* (1998), Forbes (1998), Jones (1998), Valamoti (2013)
Secondary product use – dung as building material and source of fuel	Watson (1979), Kramer (1982), Miller and Smart (1984), Miller (1996), Matthews *et al.* (1997), Anderson and Ertug-Yaras (1998), Reddy (1999), Sillar (1999), Matthews (2008), Matthews (2010), Portillo *et al.* (2014)
Indicators of vegetation and climate	Ghosh *et al.* (2008)
Manuring/fertilizer	Kenward and Hall (1997), Hall and Kenward (1998), Jones (2012a, 2012b)
Detection of animal dung using biomarkers	Bull *et al.* (2002), Shillito *et al.* (2011b), Bull and Evershed (2012)

results, and there is much scepticism over analytical performance (Frahm 2013; Frahm and Doonan 2013). Inter-instrument performance of pXRF equipment has proved that between different instruments statistically identical results are not produced (Goodale *et al.* 2012). Numerous highlighted limitations in the archaeological application of pXRF are recognised such as low precision, variable analytical accuracy, lack of instrument calibration and data correction, ignorance of surface morphology effects and difficulties with quantification due to a lack of appropriate standards (Goodale *et al.* 2012; Frahm 2013). While these limitations of pXRF are recognised, there are also advantages in using pXRF in archaeological applications such as rapid analysis, relatively good analytical precision for many elements, affordable portable technique and non-destructive analysis of samples (Goodale *et al.* 2012).

Portable XRF as a technique for elemental analysis may not be useful for *in situ* investigation of deposits in all environments and for all research goals (Frahm and Doonan 2013). However, the application within archaeological contexts to detect elevated levels of phosphorus, which are potentially indicative of animal dung, can be successful and therefore offers a useful technique that can be employed in this context. Furthermore, it can provide a basis for further in-field tests such as smear slide analysis which can confirm the presence of animal dung. Applying this methodology to our research with this specific objective provides a useful tool in the analysis of archaeological deposits, where the presence of elevated phosphorus within sediments is indicative of organic waste. Analysing modern dung samples by pXRF in comparison to a baseline dataset provided by modern natural soils provides comparative phosphorus values which can be applied to future archaeological investigations.

In addition to phosphorous values, phytoliths and spherulites may also be analysed in the study of animal dung. Phytoliths survive in dung and can provide a useful tool in archaeology for analysis of animal diet and inferring environment/ecology (Ghosh *et al.* 2008; Portillo *et al.* 2010; Shahack-Gross 2011). Calcareous spherulites are produced in the gut of animals during digestion and survive passage through the animal, they survive in dung deposits and are easily identified microscopically (Canti 1998). Numbers of faecal spherulites vary between species with sheep and goat being prolific producers of spherulites. Highest numbers of spherulites are produced by ruminant herbivores, numbers are low in omnivores and low-absent in carnivores (Canti 1999). Microscopic analysis of phytoliths and spherulites from modern dung samples provides a reference dataset that can be applied to archaeological investigations.

Methodology

Various complementary methods of investigation were undertaken in order to link the ethnographic observations and microscopic signatures of activity to scientific archaeological applications (Bendrey *et al.* 2013). These fall into three broad categories specifically designed to address our main research aims:

- *Environmental characterisation*: Was conducted to address the physicality of the landscape and provide a context in which to understand how the rural community's farming system is linked to this. The scientific analytical methodology applied for this modern characterisation also has potential archaeological applications. Specific methods employed were
    - Strontium isotope analysis of plants
    - Sampling and analysis of soils collected from the alluvial floodplains and limestone foothills
    - Oxygen isotope analysis of water (ongoing; results not included in this paper
- *Semi-structured interviews*: This used a questionnaire, but allowed discussion to expand naturally where appropriate. The questionnaire was formatted to address modern use and management of livestock within the local landscape and elucidate links between animal and plant resources. This provided information on how the rural community is connected with the physical landscape (seasonality/geography) and directed sampling concerned with exploring signatures of occupation and activity.
- *Dung sampling and analysis*: Was carried out across the village and local landscape to explore signatures of occupation and use and create reference collections that permit ethnographic data to be robustly applied to archaeological situations.

Environmental Characterisation

A systematic study was undertaken, characterising the local landscape within the local environment following a ~3 km transect across the three ecological and landscape domains identified around the village (Fig. 2). This involved the collection of samples for isotope analysis (water and plant material) and soil characterisation (soil samples for X-ray diffraction (XRD) and XRF).

Strontium Isotope Analysis

Twenty-five plant samples were collected from locations including the edges of cultivated fields and track ways, grazed fallow fields, margins of streams and the slopes of Bestansur mound. Multiple specimens were obtained for each collection with individuals selected that represented as many features of the complete plant as possible including flowers and/or fruits. Digital photographs and GPS readings were obtained for each collection (using a Panasonic DMC FZ100 camera and Garmin eTrex H, high sensitivity handheld GPS). Plants were pressed and dried before being exported to the UK and deposited at the

University of Reading and Kew Herbaria for their curation and identification.

Leaf material was submitted for isotopic analysis from five plant samples representing the three ecological/functional domains identified along the transect (Fig. 2). These samples represent a preliminary dataset that will be expanded in the future. Specimens for isotopic analysis were collected from uncultivated areas to limit the potential effects of fertiliser on the resulting strontium isotope signatures (Vitòria *et al.* 2004).

Samples were weighed into pre-cleaned pressure vessels in a clean laboratory environment. After addition of 8M nitric acid, the samples were left overnight to predigest at room temperature. Further acid and hydrogen peroxide were next added before the samples were digested in a microwave oven, the program holding them at 175°C for 20 minutes. The final digestions were then allowed to dry down overnight on a hotplate.

The samples back into solution in nitric acid and hydrogen peroxide before allowing them to dry down once more. The final stage prior to strontium separation was to convert the in 6M HCl and evaporated to dryness.

The sample was taken up in 2·5 M HCl. Strontium was separated using conventional, Dowex® AG50 X8 resin ion exchange methods.

The Sr isotope compositions were determined by thermal ionisation mass spectroscopy using a Thermo Triton multi-collector mass spectrometer. Samples were loaded onto single re-filament following the method of Birck (1986). The international standard NBS987 gave a $^{87}Sr/^{86}Sr$ ratio of 0·710254 ± 0·000006 (1SD, $n = 10$). All data are measured to better than ±0·000010 (2SE) internal precision. Strontium procedural blanks provided a negligible contribution.

Oxygen Isotope Analysis

Water samples were collected both from the Tanjero River, near its source (GPS 58), and from falling precipitation on days it rained (GPS 60). Ten water samples have been submitted for analysis of oxygen and hydrogen stable isotope composition at the University of Reading. We are currently awaiting these results for incorporation into this research; therefore, these results are not presented in this paper. Precipitation and river waters sampled in this project will act as comparative controls for likely input values to past animals, and so help interpret seasonal records, from sequential analysis of $\delta^{18}O$ values in archaeological animal teeth.

Sampling/Analysis of Soils from the Alluvial Floodplains and Limestone Foothills

In order to assess the local sediments and geology five natural soil samples were collected from two of the three ecological/functional domains, the alluvial floodplains and the limestone foothills, surrounding the modern village of Bestansur (Fig. 2, GPS points 49, 51–53 and 59). Approximately 200 g of soil was placed in a sample bag and the GPS location recorded (GPS: 49, 51–53, 59). The samples were analysed using a Philips PW 1480 X-Ray fluorescence spectrometer with a dual anode Sc/Mo 100 kV 3 kW X-Ray tube and a Siemens D5000 X-Ray Diffraction Spectrometer. These samples were also analysed prior to sample preparation on a Niton XL3t GOLDD+ portable XRF analyser so that results could be directly comparable to modern and archaeological datasets analysed *in situ* during fieldwork.

Semi-structured Interviews

Interviews provided the opportunity to collect information on how plant and animal management are integrated and function sustainably at the level of individual households within the village's structure and economy. A questionnaire was designed with an animal-based component aimed at investigating modern husbandry practices within the local landscape and the environmental context. A supplementary plant-based component explored the role and function of informant's 'kitchen gardens'. This term is used here to describe those gardens in which some, or all, of the plants being cultivated are for household consumption (also commonly referred to as 'homegardens' (Vogl *et al.* 2004) or the practice of 'garden agriculture' (Bogaard 2004)). For this, informants were asked about the purpose of their garden, what plants they grow and management strategies (e.g. seasonal planting, watering regimes) with a specific focus on links with animal management (e.g. manuring, foddering). The ethnographic data generated by these interviews helped direct modern data collection.

Dung Sampling and Analysis

A framework of strategic dung sampling was carried out with animal dung systematically sampled from animal pens in order to carry out analysis on known samples. We investigated the chemical signatures, specifically phosphorus values, and microscopic identification of dung deposits (through the presence of calcareous spherulites) and traces of animal diet, grazing/foddering patterns and how these are represented in the plant silica phytoliths extracted from the dung.

The ideal sample for XRF analysis has a flat and smooth surface, as surface irregularities introduce errors because x-rays are sensitive to topography (Frahm 2013). Within the wider Central Zagros Archaeological Project pXRF is being used to conduct minimally invasive *in situ* analyses of archaeological sediments to detect the presence of residual chemical signatures, specifically elevated phosphorus, as a potential indicator of the presence of animal dung. Therefore, unfortunately, in this context sample surfaces cannot be flat and smooth like the desired ideal sample; this represents one of the limitations of pXRF analysis of *in situ* archaeological sediments during fieldwork. For this reason, modern dung samples utilised within this research have not been prepared prior to analysis, as although it is recognised that the precision of measurements would increase with preparation through grinding, by grinding the dung samples the resulting readings would be ineffective for their intended purpose – which is to compare them to archaeological sediments that are also not prepared but analysed *in situ*. The analysis of dung samples by pXRF was therefore carried out directly in the field on raw, dried, non-prepared samples. In this study, the samples tested by pXRF are analysing total phosphorus in the samples, this approach has been applied in studies in the past for site prospection and spatial interpretations (Holliday and Gartner 2007; Roos and Nolan 2012; Hayes 2013).

Eleven modern dung samples from sheep/goats and cows were selected for preliminary analysis. Five of the six samples from sheep/goat dung were collected from mixed pens, the sixth originating from an individual young sheep. The samples were dried, then tested with the Niton XL3t GOLDD+ portable XRF analyser to characterise elements present (specifically phosphorus values). The modern dung samples were then burnt in an oven at 550°C for 4 hours to remove organic matter and *c.*100–200 mg was mounted onto a glass slide. The spherulites and phytoliths were then counted and quantified in 20 fields of view at a magnification of ×400 following a methodology similar to Katz *et al.* (2010). The numbers and types of spherulites and phytoliths could then be related back to species and comparisons made between datasets.

Results and Interpretation

Strontium Isotope Analysis

Our initial strontium isotope data indicate that the mound and fields have similar Sr values and that it may be possible to distinguish between the alluvial plain and the limestone foothills, which produced comparatively lower Sr values (Table 4; Fig. 6). It is hoped continued sampling will generate further values for each area (and the wider landscape) to support these initial findings. This would form a foundation to explore possible Neolithic animal husbandry against the baseline of ethnographic data collected (i.e. time spent grazing in the different locations).

Soil Analysis: Samples Collected from the Alluvial Floodplains and Limestone Foothills

Utilising both the XRF (Table 5) and XRD results from the natural soil samples, approximate semi-quantitative proportions of visible minerals in the natural sediments have been calculated (Table 6); this is carried out by using the approximate mass percentages.

Results from the XRF and XRD characterise the natural sediments around Bestansur as generally having a high clay content with the presence of quartz and iron-oxides. The clays that dominate these samples are predominantly montmorillonite or a similar smectite with a trace of kaolinite. The XRF results are consistent for these sediments being derived from limestone and marl bedrocks (containing calcium oxide and silicon dioxide). These results are similar to previously tested archaeological materials used to make *pise* walls at the Neolithic site of Bestansur (Matthews 2012), indicating that local sediments were an ideal natural resource for utilisation in the Neolithic village for construction purposes. Today, they are still utilising these in construction within the modern village, to build ovens/tanours, make mud bricks or to use as cement often in the construction of perimeter walls (specifically selecting the reddish rather than green clays). The results from the sediment analysis indicate that the natural material surrounding Bestansur is probably fairly sticky and

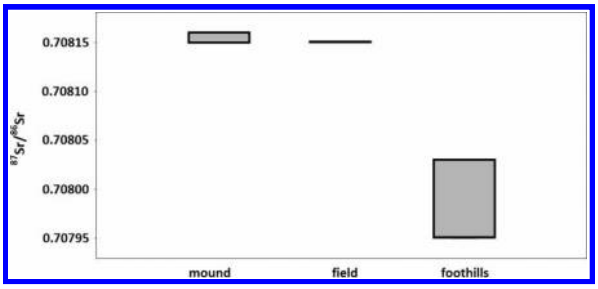


Figure 6 Strontium isotope ratios from plants growing on the foothills, fields and river catchment area (mound).

Table 4 Identification and location of collected plant samples with $^{87}Sr/^{86}Sr$ values

Collection area/GPS no.	Category	Plant identification	Material	$^{87}Sr/^{86}Sr$
Mound/GPS 47	GRASS	Wild barley (*Hordeum spontaneum* C. Koch)	Leaf	0·708152
Mound/GPS 47	LEGUME	Crown medick (*Medicago coronata* (L.) Bartal.)	Leaf	0·708161
Fields/GPS 55	GRASS	False barley (*Hordeum murinum* L.)	Leaf	0·708152
Foothills/GPS 52	GRASS	Wild barley (*Hordeum spontaneum* C. Koch)	Leaf	0·707950
Foothills/GPS 51	LEGUME	Clover (*Trifolium* sp. L.)	Leaf	0·708031

Table 5 Results of x-ray fluorescence, results displayed as major elements in weight per cent and trace elements in parts per million (ppm)

Major elements WT% oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3	Sum of conc. (%)
Sample name	Na (%)	Mg (%)	Al (%)	Si (%)	P (%)	K (%)	Ca (%)	Ti (%)	Mn (%)	Fe (%)	
CZAP 481S1 (gps 49)	0·05	3·44	16·92	64·16	0·08	0·99	2·28	1·01	0·11	9·14	98·18
CZAP 482 S2 (gps 51)	0	0·36	15·52	60·32	0·19	1·28	2·57	0·98	0·12	8·84	90·18
CZAP 483 S3 (gps 52)	0·11	3·56	16·29	63·57	0·13	1·22	2·26	1	0·14	8·74	97·02
CZAP 484 S4 (gps 53)	0·01	3·2	12·94	51·2	0·08	0·99	18·76	0·85	0·12	7·39	95·54
CZAP 485 S5 (gps 59)	0·07	0·88	2·94	20·86	0·37	0·48	56·64	0·25	0·03	1·76	84·28

Trace elements (ppm) Sample name	V (ppm)	Cr (ppm)	Co (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Rb (ppm)	Sr (ppm)	Y (ppm)	Zr (ppm)	Pb (ppm)
CZAP 481S1 (gps 49)	209	302	31	208	49	132	89	102	43	231	55
CZAP 482 S2 (gps 51)	194	289	32	201	53	163	91	123	46	227	47
CZAP 483 S3 (gps 52)	194	293	31	193	42	123	92	109	43	234	44
CZAP 484 S4 (gps 53)	145	242	31	170	41	96	55	165	31	171	47
CZAP 485 S5 (gps 59)	45	129	7	41	18	45	23	810	21	66	7

Table 6 Semi-quantitative results of minerals present from x-ray diffraction*

	Clay	Quartz	Calcite	Feldspar	Fe-oxides
CZAP 481 S1 (gps 49)	Dominant	Present	Absent	Trace	Present
CZAP 482 S2 (gps 51)	Dominant	Present	Absent	Trace	Present
CZAP 483 S3 (gps 52)	Dominant	Present	Absent	Trace	Present
CZAP 484 S4 (gps 53)	Present	Present	Present	Trace	Present
CZAP 485 S5 (gps 59)	Present	Present	Dominant	Absent	Trace

*Dominant >50%, Present 5–50%, Trace >5%, Absent-not visible in XRD scans.

cohesive, illustrating ideal properties for the use of this natural resource within the communities today.

Table 7 presents the results for P_2O_5 values recorded by the lab-based XRF, the conversion into parts per million (ppm) phosphorus, and the results for phosphorus taken using the pXRF analyser (ppm). The phosphorus recorded as an oxide on the lab-based XRF (P_2O_5) has a slightly elevated value, between 349 and 1614 ppm (when converted from P_2O_5, see Table 7). In comparison, the results from the pXRF analysis do not detect elevated phosphorus in any of the samples tested, the value is below the limit of detection (LOD) for phosphorus (<LOD). The LOD is the smallest concentration of an element that can be detected with reasonable certainty, generally regarded as indicating whether an element is present or not, but does not imply a value obtained is accurate (Niton 2014). This reinforces the reduced analytical precision of portable instruments but provides a comparable reading to the dung deposits (analysed by pXRF *in situ*) and for future comparison to archaeological deposits (also analysed *in situ*).

Semi-structured Interviews

Four families from Bestansur village were interviewed to investigate human, plant and animal interactions; three families (Households 1, 2 and 4) provided information on present day activities (Table 8 and 10), one (Household 4) on past and present activities (Tables 8–10) and the fourth (Household 3) gave information about activities *c.*70 years ago in the past (Tables 8 and 9).

The results from informants discussing past and present practices provide information on the continuity of practices over time and demonstrate that there has been a relatively recent shift in grazing patterns (Tables 9–11). In the past villagers grazed their animals on the limestone foothills for three months during the spring; a practice which is no longer in existence. The main catalyst for this change was described as the construction of the main road heading from Arbat travelling east over the border into Iran (Fig. 2). This effectively divides the landscape into two zones; the zone around the village containing the river catchment area (Fig. 3) and the farmed alluvial

Table 7 Results for P_2O_5 values recorded by the lab-based XRF and the results for phosphorus taken using the pXRF analyser

		CZAP 481S1 (gps 49)	CZAP 482 S2 (gps 51)	CZAP 483 S3 (gps 52)	CZAP 484 S4 (gps 53)	CZAP 485 S5 (gps 59)
Laboratory XRF	P_2O_5	0·08	0·19	0·13	0·08	0·37
Laboratory XRF	p%	0·0349136	0·0829198	0·0567346	0·0349136	0·1614754
Laboratory XRF	ppm P	349·136	829·198	567·346	349·136	1614·754
Portable XRF	ppm P	< LOD	< LOD	< LOD	< LOD	< LOD
P_2O_5						
P Atomic weight		30·9738				
O Atomic weight		15·9994				
P_2		61·9476				
O_5		79·997				
Weight of compound		141·9446				
Weight % of P in P205		43·6421				
Correction factor		0·43642				
1% P2O5		0·43642				
ppm (×10,000)		4364·2				

Above: Laboratory XRF values for natural soil samples as phosphorus oxide (P_2O_5), phosphorus parts per million (ppm), and ppm phosphorus values measured by the portable XRF analyser. Below: presents conversion details from P_2O_5 to ppm phosphorus

Table 8 Households interviewed

		Present practices	Past practices
Household 1	Younger adult generation	X	
Household 2	Younger adult generation	X	
Household 3	Older adult generation		X (c.70 years ago)
Household 4	Older adult generation	X	X

floodplains (Fig. 4) and the zone furthest from the village containing the limestone foothills (Fig. 5).

In addition to the changes which have occurred over time the informants also detailed the shifting patterns of land use and practice between seasons with the temporary penning of sheep/goat in the fallow fields during the summer months (Table 10 and Fig. 7), which contrasts with cattle which are always kept in yards and enclosures within the village (Table 10 and Fig. 8).

Before the 1980s with the introduction of gas cooking and heating, dung was used as a fuel (Table 9). Today, dung is only used as a fertiliser, either directly deposited onto fallow fields during grazing or penning, collected into dung heads and added to 'kitchen gardens' (Table 10).

It is also evident that integration of plant and animal resources exists in the form of local consumption at a household and village level. Both today and in the past animals were raised for meat to be sold at market (Tables 9 and 10). To some degree this integration extends more externally in the form of regional

Table 9 Questionnaires results from two families in relation to animal management in the past*

Animals		Household 3	Household 4
Number		8	50
Type		C	S/G
Milk		Yes	Yes
Meat/eggs		Sold for meat	Sold for meat
Breeding		Yes	Yes
Wool/hair		No	Yes
Dung (fuel/fertiliser)		Pre-1980's dung fuel for cooking	Fuel for heat/cooking (summer)
Other uses			Marrow
Grazing	Spring	Hills and around the mound/river/fields	Hills (3 months)
	Summer		Fallow fields
	Autumn		
	Winter	Kept in-no grazing	Hills (good weather only)
Grazing duration		During the day only	3 months day and night in the Spring
Supplementary Feed		Straw (collected in other seasons). None bought	Straw, barley
Penning	Summer	Pen for adults and pen for calves	n/a
	Winter		S/G together
Pen location	Summer	House	n/a
	Winter		House
Hunting?		Birds (in the mountains)	Fish and birds

*Key: sheep (S), goat (G) and cattle (C).

Table 10 Questionnaires results from three families in relation to present animal and plant management*

Animals		Household 1	Household 2	Household 4
Number		1/3/24	100/50/9/60	7
Type		S/C/Ch**	S/G/C/Ch	C
Milk		Yes	Yes	Yes
Meat/eggs		Eggs	Sold for meat	Sold for meat
Breeding		No	Yes	Yes
Wool/hair		No	Yes	Yes
Dung (fuel/fertiliser)		Fertiliser	Fertiliser (summer only)	No
Other uses		n/a	N/A	N/A
Grazing	Spring	Low hills close to village (C)	Fields/ river (S/G/C)	Non-cultivated fields
	Summer	Fields around the mound (C)	Fallow fields (S/G/C)	
	Autumn	No		
	Winter		Limited-river (S/G/C)	
Grazing duration		n/a	Summer 6am–6pm (S/G)	N/A
Supplementary Feed		Straw, barley, flour	Straw, barley, Alef, wheat, bad flour	Barley farmed/bought, bad flour/rice, Alef
Penning	Summer	S/C separately	S/G/C separately	Pen for adults and pen for calves
	Winter			
Pen location	Summer	House	Fields (S/G), house (C)	House
	Winter		House (S/G/C)	
Hunting?		No	No	No
Garden				
Primary function		Decorative	N/A	Food
Fodder grown		Yes – and weeds fed to livestock		No – but weeds fed to livestock
Approximate size		Small		Large
Main gardener		Mother		Father
Source of plants		Shop bought		Friends and family
Watering		Hand		Hand and sprinkler system
Tillage		Ploughed and sown by hand		Ploughed by tractor and hand
Manured (dung fertiliser)		Yes – dung from own cow		Yes – dung not derived from own livestock
Weed killer/pesticide use		Never		Never
Food plants		Onions, herbs, vines, celery, pulses		Fig, grape, almond, pomegranate, mulberry, black-eyed bean, okra, celery, leek, radish, spinach
Collection/use of plants from outside the garden/areas of cultivation		Food and fodder, not transplanted into garden		Food and fodder, but not transplanted into garden

*Key: sheep (S), goat (G) cattle (C), chickens (Ch), **and doves. Alef = purchased animal feed (straw and barley).

Table 11 Seasonal husbandry practices and land use

	Spring	Summer/Autumn	Winter
Present day	Daily grazing near the river (Fig. 3)	Daily grazing in fallow fields (Fig. 4)	Some grazing by river, but mostly fed at houses in the village
*c.*70 years ago	Three months in the hills (e.g. Fig. 5)	Daily grazing in fallow fields (e.g. Fig. 4, similar to *c.* 70 years ago)	Some grazing in hills, but not in snow; mostly fed at houses

consumption with related inputs and outputs cycled back into the local village economy (Fig. 9).

Today, household ‘kitchen gardens’ serve several purposes including provision of food, fodder and decoration see Table 10 for the list of food plants cultivated. In contrast to animal resources these are solely consumed locally; however, food plants are also purchased from regional suppliers. Although small, our preliminary dataset clearly shows variations in garden size, household gender roles and plants grown (Table 10). Overall, the local village economy demonstrates a complex integration of people, plants and animals (using both primary and secondary products), that operates at both a local and regional level (Fig. 9).

Animal Dung Analysis

Eleven modern dung samples were collected and analysed for their phosphorus content, numbers of faecal spherulites and numbers/type of identifiable phytoliths (Table 12 and Fig. 10).

Figure 7 Sheep and goats being temporarily penned in fallow fields during the summer.

Comparing the averages, it initially appears that phosphorus values are higher in the cow dung comparatively to the sheep/goat dung (Table 12). However, when calculating the standard deviation and plotting the normal distribution of these results to determine whether the probability that this observation is correct it becomes apparent that there is in fact an overlap between the distribution curves for the sheep/goat and cow dung (Fig. 11). Therefore, the probability that these values exhibit a statistical difference is low. The peak represents the mean and the spread either side of the mean is determined by the standard deviation (Fig. 11).

In order to place the phosphorus readings from dung samples taken with the pXRF in the field within the context of the surrounding natural sediments we can compare the phosphorus (ppm) and phosphorus oxide (P_2O_5) values. P_2O_5 values were obtained from the laboratory XRF for the five natural soil samples and have been converted to ppm to make comparable with the pXRF readings (Table 7). Values for phosphorus (converted from P2O5) are between 349 and 1614 ppm phosphorus and are generally lower that the phosphorus readings from the dried modern dung (with the exception of one value – Table 12). However, within this study animal dung is being analysed by pXRF in the field to enable future comparison to archaeological materials. Portable XRF results are documented to have less precision and accuracy with a lower LOD for elements. However, as portable instrumentation is utilised in the field within this study and within the wider project, these phosphorus values obtained on the modern dung must be compared against values for the natural sediments by the same means of instrumentation. Table 7 shows that the readings obtained with the pXRF (in order to be comparable) on the natural samples analysed exhibit a <LOD for phosphorus. Therefore, archaeologically when analysed by pXRF a deposit with elevated phosphorus could be indicative of animal dung, whereas a deposit with <LOD could be indicative of a natural soil.

There are clear differences between the faecal spherulite numbers, the average number counted over 20 fields of view, sheep/goat dung being 1230 spherulites in comparison to cow dung which is on average 0·6 spherulites. Distinction between sheep and goat dung has not been made in five of the six samples analysed because they originated from mixed penning (Table 12).

In general, there are very clear differences between the spherulite results between sheep/goat and cow dung. There is one clear outlier, Household 1 sheep, which produced minimal spherulites (Table 12), which can be explained by the age of the animal. The dung samples from household 2 sheep/goats derived from a sub-adult to adult herd, whereas Household 1 sheep was a young animal, *c.*6 months old. Previous analysis of animal dung from lambs and adult sheep has shown that spherulites are not produced by young animals and therefore the faeces of young lambs do not contain spherulites (Brochier *et al.* 1992). The presence of only 4 spherulites counted from Household 1 sheep dung supports this previous research, the fact that some are present

Figure 8 Cattle kept in yards/enclosures within the village.

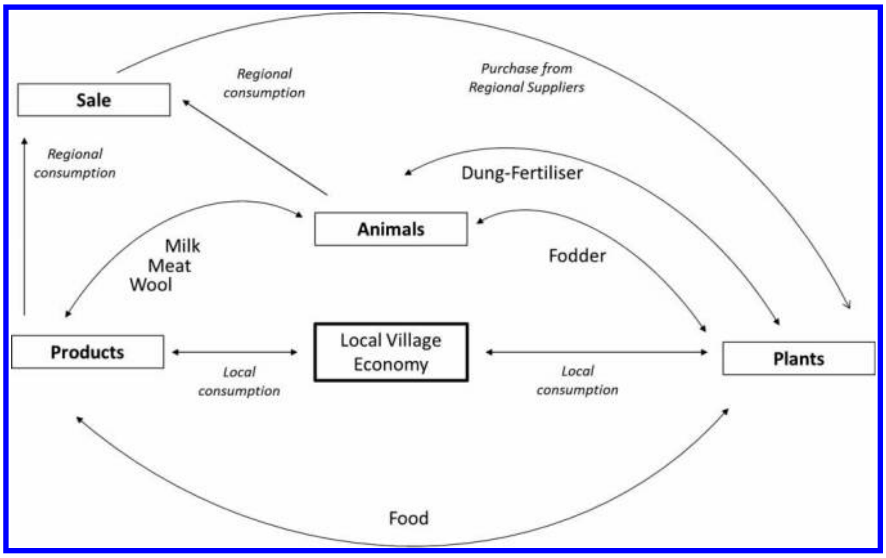


Figure 9 Animals, plants and the local economy. Simplified diagram of inputs/outputs and local/regional consumption.

Table 12 Results of phosphorus values, spherulite and phytolith extraction from modern dung samples*

	Phosphorus (ppm)	Spherulites	Phytoliths (total no.)	Monocotyledons (%)	Dicotyledons (%)	Known diet (based on data from informants)	Plants identified from phytoliths (parts and/or genus)
Sheep/goat dung							
Household 2 goat/sheep 1	9346·61	1194	47	83	17	Grass, wheat, barley (grazed on fields after harvest)	Awns, barley, leaf/stem, reed stem, wheat
Household 2 goat/sheep 2	5087·16	2210	59	89	11	Grass, wheat, barley (grazed on fields after harvest)	Awns, barley, leaf/stem, reed stem, wheat
Household 2 goat/sheep 3	4699·76	962	69	91	9	Grass, wheat, barley (grazed on fields after harvest)	Leaf/stems, reed, wheat
Household 2 goat/sheep 4	6333·97	1456	69	96	4	Grass, wheat, barley (grazed on fields after harvest)	Awns, barley, leaf/stem, reed stem, wheat
Household 2 goat/sheep 5	7390·26	1554	63	93	7	Grass, wheat, barley (grazed on fields after harvest)	Awns, barley, leaf/stem, wheat
Household 1 sheep	1879·87	4	48	100	0	Barley, straw, weeds, tree leaves, tree bark, plastic	Awns, barley, leaf/stems
Average:	5789·605	1230	59	92	8		
Cow dung							
Household 2 cow near door	15,384·5	0	96	100	0	Grass, wheat, barley (grazed on fields around river)	Awns, leaf/stems, wheat
Household 2 cow far end	15,674·53	0	108	100	0	Grass, wheat, barley (grazed on fields around river)	Awns, barley, leaf/stems
Household 1 cow 1	6785·37	2	99	100	0	Barley, straw, grass (grazed on fields around river)	Leaf/stems, reed stems, wheat
Household 1 cow 2	3865·2	0	51	98	2	Barley, straw, grass (grazed on fields around river)	Leaf/stems, barley
Household 1 cow dung heap	11,812·88	1	95	97	3	Barley, straw, grass (grazed on fields around river)	Awns, barley, leaf/stems, reed leaf
Average:	10,704·496	0·6	89·8	99	1		

*Numbers of spherulites and phytoliths counted in 20 fields of view counted at x400 magnification. Phytoliths divided by monocotyledons (grasses) and dicotyledons (shrubs and trees) and an indication of any specific plant material identified.

could perhaps represent the beginning of faecal spherulite production.

The phytolith morphotypes identified were similar in both sheep/goat and cow dung. These findings are supported by the results from the semi-structured interviews, which suggested that there was little variation in the diet of sheep/goats and cows (Tables 9 and 10). However, there is a higher average percentage

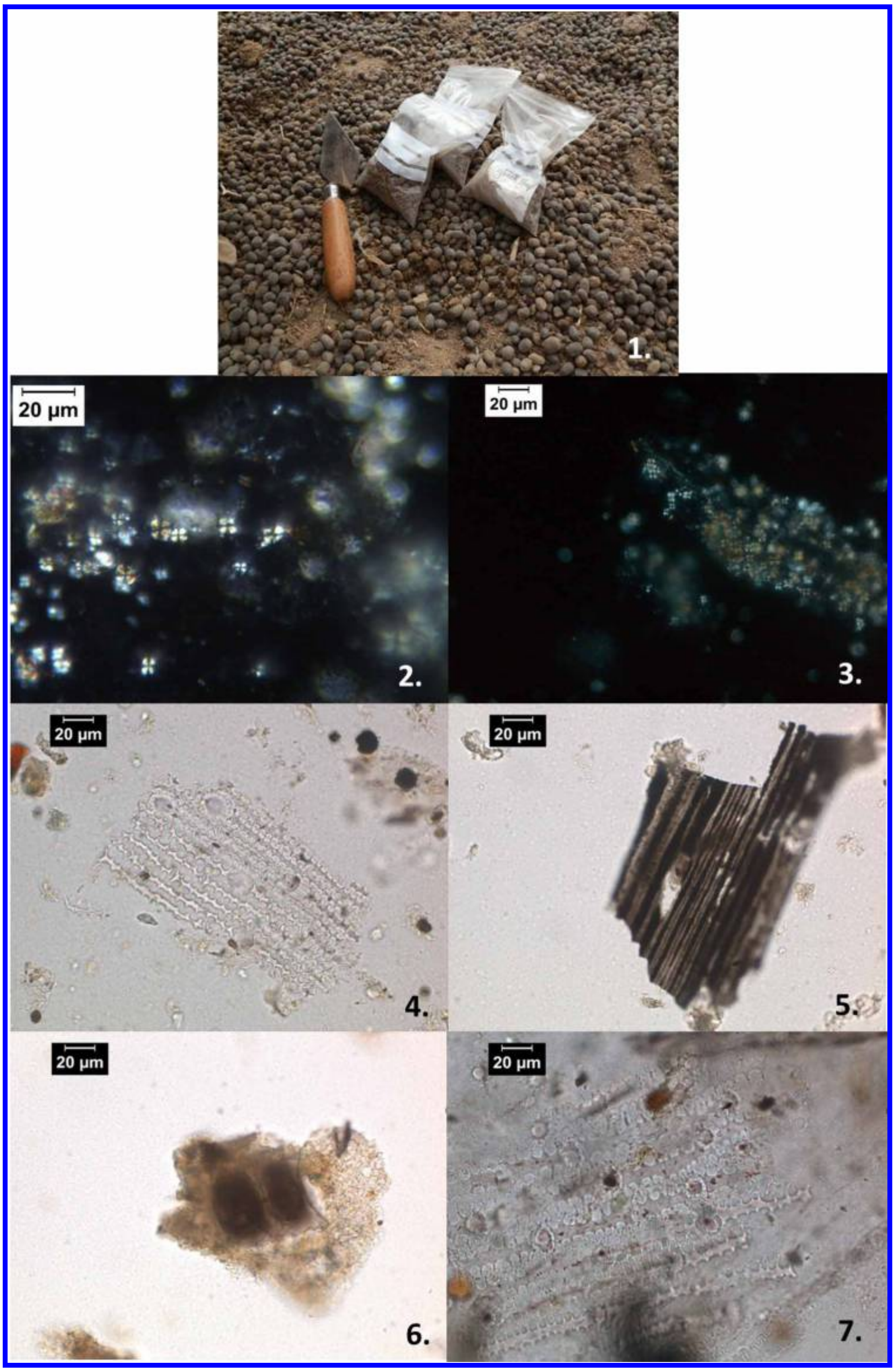
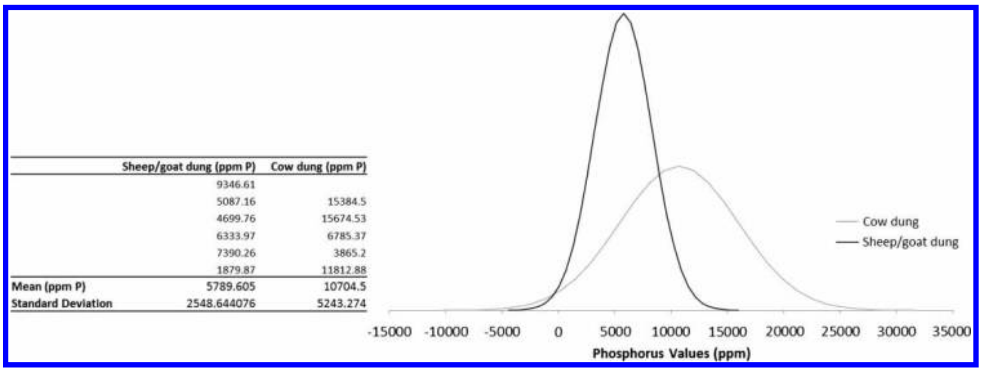


Figure 10 Phytoliths and spherulites have been extracted and quantified from the dung collected from sheep/goat pens and cow sheds in Bestansur. 1: Dung samples being collected from sheep/goat pens. 2: Spherulites from sample 'Household 2 #2'. 3: Spherulites from 'Household 2 #3'. 4: Multicelled elongate dendritic husk phytoliths from *Hordeum* (barley) from 'House hold 2 #4'. 5: Multicelled elongate smooth phytolith from grass stem/leaves from sample 'House hold 2, cow far end'. 6: Stacked multicelled bulliform phytoliths from *Phragmites* (reed) from sample 'Household 1 cow #1'. 7: Multicelled elongate dendritic husk phytoliths from *Triticum* (wheat) from sample 'Household 1-Cow dung heap'.

of dicotyledon phytoliths in the sheep/goat dung (8%) in comparison to the cow dung (1%). This suggests that sheep and goats are more prone to browsing on the leaves of shrubs and trees than cows. This small 7% difference is significant due to the limited production of phytoliths within dicotyledonous plants in comparison to prolific phytolith production in monocotyledonous plants (Shillito 2013). Dicots produce very low numbers of phytoliths up to twenty times less than monocots (Albert *et al*. 2003; Jenkins and Rosen 2007). The diet of Household 1 sheep was known to include tree leaves and bark, but conversely



	Sheep/goat dung (ppm P)	Cow dung (ppm P)
	9346.61	
	5087.16	15384.5
	4699.76	15674.53
	6333.97	6785.37
	7390.26	3865.2
	1879.87	11812.88
Mean (ppm P)	5789.605	10704.5
Standard Deviation	2548.644076	5243.274

Figure 11 Normal distribution for sheep/goat and cow dung showing the bell-shaped density curve described by its mean and standard deviation. The Peak represents the mean and the spread either side of the mean is determined by the standard deviation.

no dicot phytoliths were recovered from the dung sample. This sample was collected from an animal kept within the property enclosure of the household and not grazed daily and whose diet was observed to be relatively variable and inconsistent. Therefore, the dung sample could have been collected from a sample that represented a period of time when only monocots had been consumed. In comparison, the animals from Household 2 were taken out to graze along the same daily route. Therefore, the phytolith assemblage observed in the dung samples obtained from these animals represents a consistent and repetitive diet.

These results give an indication of the variation between species and the specific composition of the different animal dungs; this information can then be used in the analysis of archaeological dung deposits. The distinction between types of animal dung identified in micromorphological thin section can be inferred by the numbers of faecal spherulites and the phytolith assemblage present. However, the analyst must always take into consideration taphonomic processes that affect the deposition and burial of animal dung, as well as the context that the deposits are recovered in. These samples analysed in this small dataset are unburnt animal dung samples collected from the surface (meaning they have not been subject to subsurface taphonomic processes). The recovery of dung in various archaeological deposits will result in differential preservation of the dung, these deposits include middens, ash, compacted pen deposits, building materials. Faecal spherulites dissolve/degrade in a pH of above 7 (Canti 1999) and above temperatures of approximately 650–900°C (Matthews 2010). Phytoliths do not survive in a pH above 8·5 and silica phytoliths melt at temperatures of above approximately 850°C (Canti 2003).

Discussion, Conclusion and Future Direction

The preliminary results presented here come from a small dataset, but indicate that a huge wealth of information is embedded in local rural communities which can be readily accessed and utilised to aid archaeological interpretation. Such information risks being lost as these practices and traditions are being abandoned and younger generations lack the first-hand experience and knowledge of their forbearers. However, by recording oral histories of the rural life of this area we are learning about changing practices and relationships within the surrounding countryside. The marked differences between the practices of families with large and small herds as well as the contrast to just *c.*70 years ago highlights the need for extensive investigation into local knowledge, the continuity of these practices over time and how they are constrained within the local landscape.

Analysis of species-specific dung samples has enabled the assessment of variation in spherulite production, phytolith concentration and phosphorus values across different species. While the phosphorus values generally appear higher in cow dung, the overlap of the normal distribution curves shows that this difference is not statistically significant within the small dataset analysed. The dung samples analysed exhibit a clear variation in faecal spherulites between samples from different species. Adult sheep/goats produce more spherulites in comparison to cows; however, clear outliers have been recognised in the form of low faecal spherulite production in immature sheep. The archaeological interpretation of animal dung to species should therefore be cautiously used without further clarifying evidence, for example species specific GC MS (see Bull *et al.* 1999; Shillito *et al.* 2011a). This variation between species observed in this preliminary dataset reinforces existing work on spherulite production (Canti 1999) but also provides a region-specific dataset comparable within the environment of our archaeological study area (Figs. 1 and 2). The average percentage difference in dicot phytoliths suggests that sheep and goats generally are more prone to browsing on the leaves of shrubs and trees than cows. The absence of dicot phytoliths from

Household 1 sheep dung can be attributed to specific grazing patterns and inconsistency in feeding regimes. These results have potentially significant implications for the interpretation of variations in archaeological dung signatures found across Early Neolithic sites. To date, only herbivore dung has been analysed within this study and as an expansion of this reference collection we will collect and analyse dung from a wider range of animals within the vicinity of Bestansur including separate sheep and goat samples and omnivores.

Results from preliminary isotope analysis demonstrate measurable variation exists in the physical environment. This is based on a number of small datasets, which will be expanded in the future, to test whether the differences in the values present here are significant and meaningful for archaeological applications. Areas around the archaeological mound at Bestansur and the farmed fields of the alluvial floodplain have different strontium isotope values compared to those in the limestone foothills. These control data can be used as a framework to infer seasonal landscape movements, or not, of analysed Neolithic animal remains in relation to the underlying geology. Isotopic analyses of local river and precipitation samples taken at different times of the year will also act as proxy control data for input values to the archaeological livestock in the final analysis. Further collection and analysis of samples is planned to substantiate the pattern identified here. Plant and water samples collected during the spring 2013 field season are currently being considered for strontium and oxygen isotope analysis.

This first phase of ethnoarchaeological research at Bestansur has mainly been exploratory with subsequent phases designed to more rigorously test our preliminary findings. Future expansion of this dataset is also required, with additional families (locally and regionally) being interviewed, and further laboratory analysis on existing samples collected during this first phase of ethnographic study at Bestansur. Additional work currently being carried out includes assessing the changes which occur in dung signatures as a result of exposure to fire (Elliott *et al.* 2013). The recovery and identification of charred macrobotanical assemblages originating from animal dung in archaeological deposits at Neolithic sites in Southwest Asia has been frequently discussed (Miller and Smart 1984; Miller 1996; Charles 1998; Wallace and Charles 2013). Carrying out experimental dung burning would therefore enable an expansion of the reference collection, which can be linked back to the archaeological data, for both macrobotanical and phytolith assemblages. It will enable us to observe taphonomic changes and preservation of the components in different types of dung resulting from exposure to fire. We are also currently undertaking a review of grazing patterns based on discussion with informants and direct observation of both sheep/goat and cattle herds (involving an integrated programme of GPS mapping of mobility). By directly observing animal herds and their grazing patterns, information that may have been ‘lost in translation’ or unintentionally omitted is gained. For example, the duration and pattern of grazing enables observations between preferential grazing and ‘accidental grazing’ of animals in transit.

This ongoing research is generating a more meaningful and accurate dataset to inform on, and link back to, our archaeological material.

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