Satellites and Site Destruction: An Analysis of Modern Impacts on the Archaeological Resource of the Ancient Near East

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Abstract: **Satellites and Site Destruction: An Analysis of Modern Impacts on the Archaeological Resource of the Ancient Near East**

Emma Cunliffe

The increasing damage to archaeological sites is of particular issue in the Near East. Rapid modernisation has dramatically changed the landscape, threatening the archaeological resource. Ancient sites and relict landscapes are particularly well preserved here, but the rate of anthropogenic damage is shown to be increasing markedly.

This primary aim of this thesis is to use sequential satellite images to examine the changes to archaeological sites in selected case study areas in Syria, and attempt a quantitative assessment. Results are then generalised to the wider Middle Eastern region. The secondary aim is to demonstrate the potential of low cost and free satellite imagery for archaeological site monitoring, as such work is essential but the cost of custom-ordered imagery is prohibitive for many organisations.

The case study areas were Tell Beydar in the Upper Khabur Basin, and the region south of Carchemish by the Euphrates. 161 sites were examined, first on low-cost Corona imagery from the 1960s, showing sites at the advent of the landscape change, and then on SPOT, DigitalGlobe and Geoeye imagery from the last decade, available through Google Earth. The sites were surveyed as part of Durham University's Fragile Crescent Project, and the survey records used to inform the analysis. Some level of assessment was possible on all sites.

The concept of damage was examined and refined, and then applied to the case study sites. Multiple anthropogenic threats were examined, and all were quantitatively shown to be increasing in horizontal extent across sites and vertical depth in both case study areas, often causing extensive damage. Almost no sites were unaffected. Finally, key issues from this study are highlighted and key recommendations made.

Satellites and Site Destruction:

An Analysis of Modern Impacts on the Archaeological Resource of the Ancient Near East

Emma Cunliffe

~ Volume 1 of 3~

~ Chapters 1 to 4 ~

Ph.D. Thesis, Department of Archaeology
Durham University 2013

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Land of Carchemish	One of the areas surveyed as a part of this study – Chapter 7- Case Study 2: Context to

Project (LCP)	the Land of Carchemish Survey Area, p299
Land Use/Land Cover	A record of the state of the land at the time of a survey Section 4.5.5 – Recording Change: Type and Extent of Damage, p144
LCP	Abbreviation for one of the areas surveyed as a part of this study – 2.5 – Case Study 2: The Land of Carchemish Project
- Majority/ Extensive	Category of Horizontal Damage Extent Section 4.5.5 – Recording Change: Type and Extent of Damage, p147 Table 4-4: Definitions of Database Fields for Horizontal Damage Extents, p149
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Principle of Least Damage	The principle that only the least possible damage that can be confirmed should be assumed Section 4.7.3 - Damage Certainty, p161
- Sectional/ Partial	A Category of Horizontal Damage Extent Section 4.5.5 – Recording Change: Type and Extent of Damage, p147 Table 4-4: Definitions of Database Fields for Horizontal Damage Extents, p149
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	Type and by Site Unit, p163
Site Unit	Individual sites, some of which may be combined into an amalgamated site for some analysis Section 4.8.1 – Analysis by Amalgamated Site Type and by Site Unit, p163
SPOT 2004	A set of satellite images Section 4.3 – Remote Sensing – History and Value, p120 Table 4-1: Details of Imagery Used in the Study p123
Survey Areas	The areas used in this study Chapter 5 - Case Study 1: Context to the Tell Beydar Survey Area, p170 Chapter 7 - Case Study 2: Context to the Land of Carchemish Survey Area, p299
Tell Beydar Survey	One of the areas surveyed as a part of this study Chapter 5 - Case Study 1: Context to the Tell Beydar Survey Area, p170
- Total/ Wholesale	A Category of Horizontal Damage Extent Section 4.5.5 – Recording Change: Type and Extent of Damage, p147 Table 4-4: Definitions of Database Fields for Horizontal Damage Extents, p149
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- Unknown	Category of Vertical and Horizontal Damage Extent Section 4.5.5 – Recording Change: Type and Extent of Damage, p147 Table 4-4: Definitions of Database Fields for Horizontal Damage Extents, p149 Table 4-5: Definitions of Database Fields for Vertical Damage Extents
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Unit Analysis	Individual sites, some of which may be combined into an amalgamated site for some analysis Section 4.8.1 – Analysis by Amalgamated Site Type and by Site Unit, p163
Vertical Damage Extent	An estimate of the depth to which a site is likely to have been damaged by a particular source Section 4.5.5 – Recording Change: Type and Extent of Damage, p147 Table 4-5: Definitions of Database Fields for Vertical Damage Extents, p152
Visibility	Categories of how visible sites are on satellite images Section 4.5.3 – Recording Change: Visibility, p138 Table 4-2: Definitions of Database Fields for Visibility of Sites on Imagery, p139
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Statement of Copyright

Acknowledgements

This thesis could not have been completed first and foremost without the continuing support and assistance of my supervisors, Professor Tony Wilkinson and Professor Graham Philip, and the generous support of the AHRC.

A debt of gratitude is also owed to the Global Heritage Fund, Durham University Department of Archaeology, Trevelyan College, and BANEA for their generous help.

Thanks are also due to Dr Jason Ur of Harvard University for his data, to the members of the Fragile Crescent Project for all their assistance, particularly Dr Dan Lawrence, and to Dr Galiatsatos and Louise Rayne for their kind permission to use their work.

Special thanks are due to Derek McAllister, Rafe and Beth Richards, and Jennifer and David Leach for their invaluable help preparing this thesis, and in particular to my parents, and most of all to my husband, for their unfailing and generous support, no matter what.

Finally, thanks are due to Dr Lynda Boothroyd, Durham University, for believing in me when I didn't.

"Unless steps are taken to halt the destruction (or at least to record what is being destroyed), very little of the ancient landscape and archaeological sites will remain for future generations to study"

Professor T.J. Wilkinson

Archaeological Landscapes of the Ancient Near East (2003: 219)

This thesis represents a first step in monitoring the destruction of the archaeological resource of the Near East, providing a benchmark against which damage can be assessed in order to assist in the recording - and hopefully the protection - of these fragile and important remains.

It is dedicated with gratitude to Professor Wilkinson.

"The many drawings I made of these views upon the plain are for pure necessity … to perpetuate the vestiges of this celebrated wonder … for I foresee that it will in a few years be universally ploughed over, and consequently defaced".

~ William Stukeley (1687 – 1765) ~

~ In (Burl and Mortimer 2005: 126) ~

Chapter 1:
Introduction

1.1 – Opening Remarks

Almost 300 years ago, Stukeley remarked on the damage to what would become some of the most iconic monuments of the English landscape - Stonehenge and the Avebury Plain. He was perhaps the first to note the long-gone avenue which once led to Stonehenge, discerning its former existence from the hollows remaining, and the first to predict the damage that would occur to sites across the English landscape. It was not until the twentieth century and the advent of aerial photography that his theory was proved correct and the true extent of the damage to this ancient site would become known.

Three hundred years later, sites in the Middle East face the same threats, and archaeologists face the same challenge – to assess the damage and record the sites before they are lost to us forever. Unlike Stukeley, however, archaeologists may now possess the tools to not only assess the damage, but to prevent it through creating targeted protection policies. The landscape of the Middle East is changing: towns and industry are expanding, agriculture is intensifying and as the population grows, even marginal land is brought under cultivation. Although archaeologists have studied damage occurring to sites, the focus has largely been on conflict and periods of unrest. However, as Stukeley recorded 300 years ago, the damage caused in peace can be even greater than that occurring today during war.

The archaeological significance of the Near East cannot be overstated. The earliest farming, cities, writing, law and countless other achievements are all found here. The history of occupation stretches back to the earliest hominids: there is virtually no period where man was not present, and evidence of this occupation is ubiquitous. Of particular note is the remarkable preservation of the Bronze Age and later landscapes. In some areas, such as the Jazirah of Syria and Iraq, or the area around Homs, entire relict landscapes were preserved until very recently, complete with ancient fields, water management systems, and road networks connecting ancient towns, villages and farmsteads. However, the sites and features of the past are so dense that it is impossible for modern society to supply its needs without seriously impacting upon them. Unfortunately there has been little study of the effects of the modernisation accompanying economic prosperity on sites. As a result, these damage threats have never been quantified and are frequently underestimated.

Whilst not all heritage can be saved, and its attrition through development is all but inevitable, those sites which are selected for preservation should be representative of the archaeology of the period, of the local area, and of the modern nation in which they are located. Samples should be chosen with care, and with a deep understanding of the complexities of archaeological resource and its interrelations (Darvill et al. 1987). Although some countries do have systematic selection processes to determine which sites and monuments should be marked for preservation, few Middle Eastern countries do. Sadly, the speed at which sites are being lost, and the lack of records for many of them, means that the extensive information necessary to establish a systematic selection process is simply not available. The risk is that without a better understanding of the problem, what is saved may ultimately be what is left.

The damage to sites also limits archaeological understanding of the area. Aside from the direct loss of knowledge resulting from site destruction, if sites are destroyed before they are recorded, the settlement pattern will be biased. Many studies of settlement patterning use site size as a comparative characteristic: the degradation of a site could play a key part. In order to interpret both the settlement and landscape record with accuracy, it is essential to understand how much has remained from an earlier period, or conversely, how much of that record will have been lost by attritional taphonomic processes: in many cases what remains is only a small fraction of what was originally present. However, whilst studies have examined the extent to which these taphonomic processes can limit site recording, the focus is often on natural physical processes: there has been comparatively little study of modern cultural impacts.

An increasing population has a real need for shelter, food and a better quality of life. These needs can only be met by more intensive utilisation of the landscape, but unless this forms part of a major planned work, such as a dam or large irrigation project, no archaeological assessment or rescue work is usually carried out. Even then, limited definitions of the terms "sites" and "heritage" have meant that a great number of archaeological landscape features have been lost with no record made. Rescue work conducted in Syria in advance of the Tishrin Dam on the Euphrates focused largely on major Bronze Age sites, ignoring landscape features and small sites of other periods. (This will be discussed in more detail in Chapter 7). Without understanding the range and impacts of anthropogenic threats, limited conservation resources cannot be appropriately targeted, and the remarkable heritage of this important area is at risk.

1.2 - Background and Context of Thesis

To provide the data necessary to inform protection policies, this work uses selected case studies to investigate damage to sites, examining what is meant by damage, and to establish the main contributory factors. Much as the term *site* is contested, the term *damage* is rarely defined and poorly understood. It is often treated as a 'catch all', covering everything from slight degradation to utter destruction. In order to study damage, it is necessary to consider how the term is used, and what it refers to, as well as the different causes and ways of recording it. By elaborating on and redefining our understanding of this term, quantitative methods of analysis can be applied, providing data which can be used to support policies relating to site preservation, and thus directing the focus of efforts to where it is most needed.

There have been very few studies on site damage, and even fewer using remote sensing methods. The most notable are: the Monuments at Risk Survey (Darvill and Fulton 1998), which studied site damage across the whole of England, looking at ways to monitor it; Parcak's remote sensing survey of site damage in Egypt (2007); Van Ess et al. (2006) and Stone's (2008) remote sensing surveys of looting in Iraq. These, and others, are reviewed in Methodology Chapter 4, and their important contribution to this work is acknowledged. Other relevant literature is referred to in the appropriate sections: remote sensing is discussed in the Methodology, for example, whilst the available work on damage has been reviewed in Chapter 3: Damage – Definitions and Types (although previous research, with few exceptions, has been limited). Survey areas and relevant information about them are detailed in Chapter 5 and 7.

The research sits within the overall framework of the Fragile Crescent Project (FCP), which is based at Durham University. The Project, detailed in Chapter 2, seeks to understand settlement patterns across the whole of the Fertile Crescent. The area offers the opportunity for an unparalleled study of multiple sites over a history spanning thousands of years. The Project examines the landscape in terms of the people who lived there, and seeks to answer questions about the entire range of human activity – economic, social, pastoral, technological and ritual – and the way in which these spheres interacted and changed over time. Perhaps the most important feature of the Project is the manner in which it incorporates both localised excavation of individual sites, and much wider settlement patterns across a huge geographical area. By integrating the depth of one with the scale of the other, a far deeper and more coherent understanding can be achieved.

Although data was available for most countries in the Fertile Crescent, Syria was chosen as the study area. The last fifty years have been a period of relative prosperity, and the country has undergone marked urban and agricultural expansion, affecting the archaeological resource. Large amounts of relatively comparable archaeological survey data were available for different areas, compiled by the FCP, and the collection of new data was possible (at the time) due to the departmental links with the Directorate-General of Antiquities and Museums via two current field projects.

The study areas chosen were a completed survey in the Syrian Jazirah, around the Bronze Age site of Tell Beydar, and an on-going survey south of the ancient city of Carchemish on the Syrian-Turkish border. These areas were both surveyed by the FCP team with the intent to provide the most comprehensive settlement record possible. They contain 83 and 78 sites respectively, providing comparative sample sizes. The methodology used involved comparing the appearance of the sites on sequential satellite imagery, informed by the field data. The earliest available imagery was 1960s Corona satellite photography, which was compared to recent imagery (mostly from Google Earth) in order to understand and record the extent of site destruction, and begin to identify the factors that may contribute to site preservation. Corona imagery provides a record of the landscape at the advent of modernisation: changes in site appearance and emerging threats can thus be examined over time. A database was created to record damage to each site, and new categories of damage were defined to assist analysis. Statistical analyses were conducted wherever possible to give quantitative validity to the results.

Nonetheless, it is not possible to develop remote methods of analysis without some level of on-the-ground verification. The interpretation of satellite imagery is difficult: complexities include resolution, visibility and subjective interpretation. Therefore, as well as utilising the FCP field records, I undertook fieldwork. There were two strands – visiting major sites in Syria, including World Heritage sites and sites of national importance, like Tell Beydar, gaining an understanding of the Syrian Jazirah, and visiting sites around Carchemish which are threatened by a variety of modern impacts. These visits studied how damage which is visible on imagery appears on the ground, and conversely what may be visible on the ground but cannot be seen on imagery. Through such ground verification, the remote sensing methodology was validated and refined. The fieldwork also gave me an appreciation of the cultural and environmental context of heritage sites in Syria.

It should be noted that the intent had been to conduct a final field season in Syria to refine the methodology and to investigate additional sites. Unfortunately, the on-going conflict meant no further fieldwork was possible.

1.3 – Aims and Objectives

Main Aims: This research used comparative sequential satellite imagery of selected case study areas in Syria to examine damage to sites, assess the key impacts, and develop principles of site damage in order to better protect them. Once we know the extent of what is lost, we can better understand what remains, and how to preserve it for the future.

> *Objective:* Concepts of damage have been examined and redefined in order to better evaluate the processes affecting sites.
>
> *Objective:* It was necessary to develop a new methodological framework in which to conduct the research as damage *per se* has rarely been studied. This focuses primarily on cultural processes of destruction, although the effects of physical processes are also acknowledged, particularly where they interact with the former.
>
> *Objective*: This framework was tested with fieldwork which developed the interpretation of damage as it appears on satellite imagery.
>
> *Objective:* In part because of the subjective nature of the concept of damage, this study was specifically designed to utilise quantitative methods which

would provide hard data, supported by qualitative studies of small areas, or individual sites where appropriate.

Secondary aim: This study includes a viable, widespread sample of sites, but it was not possible to visit them all. The Fertile Crescent has literally thousands of sites (there are some 9,900 in the FCP database alone): it is not feasible for any designated responsible agencies to monitor them all on the ground. Other studies have used expensive custom-ordered imagery, but the recent availability of free high resolution imagery on Google Earth offers great potential. The second aim of this study was to determine whether damage monitoring could be carried out remotely, using cheap or freely available imagery with little technical expertise required.

Objective: If successful, other agencies with limited funding and / or technical expertise should be able to use the methods developed to monitor sites in their care.

1.4 - Thesis Structure

Chapter 2 provides a contextual overview, in which the Fragile Crescent Project (of which this study is a part) is detailed. The broader regional, environmental and historical contexts of the sites are described, which will enable extrapolation of the results to the wider area. Important terms, such as 'site' are defined, as are the limitations of this study, including specifying deliberately excluded areas.

Chapter 3 builds on this context to examine the types of damage that sites have undergone across Syria. Damage is discussed according to significance, cause, and extent. Whilst primarily focused on the Middle East, research on certain types of damage is only available from European studies. Where this is the case, if possible it is extrapolated to a Middle Eastern context.

Chapter 4 covers the methodology developed and the fieldwork undertaken to support the study. This chapter also includes a brief review of previous studies which have influenced the creation and design of the methodology, as well as a summary of remote sensing literature. In order to record the damage to sites, a database was created to aid standardised recording and analysis. The theory behind the database creation is explained, and new terminology defined. The different imageries used and the caveats of each are explained, as well as the remote sensing methods used. Methods of analysis are also listed. Some more detailed sections, such as the codes developed for error checking, and technical details relating to the use of imagery, are in the appendices.

Chapter 5 describes the first case study area in detail – the Tell Beydar Survey in north east Syria. Elaborating on the regional context given in Chapter 2 and the damage types discussed in Chapter 3, the localised situation of the sites is described – the survey history of the area and the sites that will be examined, the physical environment, and then finally the settlement history of the region up to the modern day.

From this historical and environmental context, Chapter 6 applies the methodology to the sites in the Tell Beydar area, and analyses the results obtained.

Chapter 7 details the local context and history of the second case study – the Land of Carchemish Project – and Chapter 8 analyses the damage to sites in the area. Both analysis chapters explore the damage in the specified area, looking at general trends, causes and extent, and considering influential factors such as site location and type, finishing with a review of key findings. Only the most important tables and graphs are included in the chapters – most supporting data is in the appendices.

Finally, the two areas are compared in Chapter 9, which is structured in line with the preceding chapters.

The last chapter - Chapter 10 - contains conclusions of the study, detailing principles of damage and preservation, and recommending ways forward.

The appendices contain additional supporting information for the thesis. Supplementary information for the Methodology (Chapter 4) includes:

- Appendix A - Image Processing Details and Dates.
- Appendix B – Visibility, Feature Identification and Damage Extents.
  This Appendix contains examples of these with supporting images.
- Appendix C – Field Verification: Soil Samples
  This Appendix contains details of the soil samples taken and tests carried out in the field to examine the visibility and spectral signatures of sites, to confirm the imagery results.
- Appendix D – Error Checking.
  This Appendix contains details of the error checking used to support the data collection.
- Appendix E – Statistical Methods Used.

The other appendices contain the supporting data for the case studies:

- Appendix F is the key to each table and graph along with how to read them and what they show.
- Appendix G provides the supporting graphs and tables of information for the Tell Beydar analysis.
- Appendix H provides the supporting graphs and tables of information for the Land of Carchemish analysis.
- Appendix I is a CD containing the database.

1.5 - Additional Remarks

The scarcity of published literature on this topic, both in the Near East and more widely, will be demonstrated throughout this thesis. There is a need for a greater understanding of damage to sites in this remarkable area, in order to protect them and to better understand them. Current information is over-generalised and inadequate: policies of protection based on it would be similarly inadequate.

Archaeologists and heritage specialists have traditionally focused on large sites of known historical importance, but the density of sites of all periods across Syria is high. It is no longer enough to focus only on the kings and princes of history, and on the capitals of empires. The strength of Syria's heritage is that it includes not only empires, but the continuous occupation of all mankind: fields and farmsteads are as well preserved as palaces. However, the focus on major sites has left these smaller sites at the mercy of modern expansion. Unless strategies can be developed to preserve them, or at least record them, they will soon be lost, and with them all the information they contain, and future scholars will be left to work with a highly skewed sample of the ancient settlement record.

This thesis hopes to make the first step towards this. By exploring and quantifying the extent of the damage, the true loss to the archaeological heritage of Syria, which can act as an indicator for the rest of the Near East, will be known. This in turn will enable heritage experts and professionals to better understand this unique past and preserve it for the future.

"I would be shown a number of sites that were endangered by natural or man-made intrusions in eastern Syria. … I [added] a final paragraph saying that … it had on it a village that was continuing to grow, and that it even had a paved road through it. Clearly the site would be lost to archaeology fairly quickly if something were not done...

This process of modern re-occupation and farming of an area that was, for centuries, essentially pastoral, is only the latest evidence of a fluctuating pattern of settlement and abandonment…"

~ McGuire Gibson (2010: xxi) ~

Chapter 2:
Studying Damage in its Context

2.1 – Introduction

This study is, in many ways, a survey of the archaeological landscapes of Syria, yet unlike others of its kind, it focuses on modern impacts affecting sites. Whilst no archaeological survey can be divorced from its modern context, the aim is usually to unravel the palimpsest in order to reveal what has gone before.

Wilkinson (2003: 3) defined landscape archaeology as being

> *"concerned with the analysis of the cultural landscape through time. This entails the recording and dating of cultural factors that remain, as well as their interpretation in terms of social, economic and environmental factors" (adapted from Kincey and Challis 2010).*

In that sense, there is nothing archaeological about this work, yet it owes a great debt to those who have developed methods of landscape study (Allen 1991; Aston 1985; Bowden and Royal Commission on Historical Monuments 1999; Bradley 2000; Everson and Williamson 1998; Finlayson and Dennis 2002; Howard et al. 2008; Muir 1999; 2000; Rossignol and Wandsnider 1992; Schiffer 1983; 1987; Valdés Pereiro 1998), and who have studied the Near Eastern landscape in particular.

The first comprehensive, overall study of the Near Eastern landscape was published by T. J. Wilkinson in his seminal volume, *Archaeological Landscapes of the Near East* (2003). It is ironic that this volume, which compiled a multiplicity of previously disparate sources into a unified picture of the Near East, was published at a time when archaeologists were just coming to realise the sweeping changes occurring to that landscape. These changes are part of a cycle that has repeated itself for millennia - the landscape does not stay the same – but the rate of on-going attrition is now much greater. Modern technologies are damaging and destroying sites with alarming speed. Unless archaeologists and planners can understand these changes, and develop ways to deal with them, large parts of the archaeological resource will be lost. This study intends to do just that – to examine and understand the damage occurring to sites, and to place it in its regional and local context. This context is crucial: building materials, chronologies, historical and environmental factors, and many other aspects all influence how and why damage occurs to sites.

This chapter sets out a comprehensive regional context for this study, delineating its scope and coverage, the historical, political and environmental setting. Important terms such as 'site' are considered, as well as the types of data the study is built on. Without this, observed local trends in site damage cannot be extrapolated to the wider Middle East. The archaeological surveys conducted in this region which inform this research are part of the Fragile Crescent Project. They aimed to locate and analyse the distribution of ancient settlements and features in order to form a framework for understanding the region over time. From this regional foundation, key concepts relating to site damage can then be explored, informing the survey specific analyses.

2.2 – The Nature of the Archaeological Resource in the Near East

The present landscape represents the choices (deliberate or otherwise) made by millennia of generations and institutions, shaped by the natural world around them. It is a palimpsest formed from "progressive superposition of one landscape on another and sometimes selective removal of parts of the earlier landscapes by later landscapes" (Wilkinson 2003: 7). With an occupation history spanning millennia, the archaeological resource in this area is varied. Settlement has been both sedentary and nomadic, pastoral and arable, and every conceivable combination of the spectrum in between. The oldest sites are now no more than flint and artefact scatters, organic remains and archaeological soils long homogenized into ancient soil horizons. As a result both natural (e.g. ecological, geomorphological, hydrological) and cultural (e.g. symbolic, economic, social) variables are integral parts of any study of the landscape.

Context is key to interpretation, and varies throughout time: in particular, it is important to understand what is meant by 'site' in a Near Eastern survey context. Although it is likely that human activity has occurred at most locations at some point, archaeologists are, of course, restricted to studying places where evidence remains. Intensive surveys across the region and developments in theoretical perspectives have shown that the landscape is an almost continuous record, not limited to often arbitrarily defined 'sites', causing problems both in how 'sites' are defined, and how interpretations of the landscape are approached (Bintliff 2000). Some archaeologists have left the definitions deliberately vague:

> *"Within the whole landscape certain areas are held to contain greater archaeological information than other areas and it was these areas we defined as 'sites' "* (Drewett, 1980: 69).

Gallant (1986) summarised the main definitions of 'sites' used by archaeologists (often relating to the density of sherds). Notably, it is pointed out that sherd densities must be evaluated relative to the densities found elsewhere in the area, and flexibility is therefore key. Gallant's definitions are:

1 – no definition applied - sites are assumed to be easily and obviously recognisable as such, often identified by the presence of any dateable sherds;
2 – vague definitions – sites are any location where human activity is identifiable; specific sites are thus hard to distinguish;
3 – rigid criteria are applied, such as number of sherds per metre squared, or within a certain radius; however, these are often arbitrary and may accidentally exclude sites.

Occupation of locations which became archaeological sites is not composed of neat phases, chronologically, spatially or vertically.

> *"All 'sites', in any survey, are interpretations of the artefact record. If we are to use the word 'site' at all, even as a shorthand for discrete spatial units representing high densities of artefacts, then field 4200 is a site in the same way as field 4649 represents a 'site'. Whereas the latter is a Roman courtyard villa, however, the former is apparently a heavily manured group of allotments, distinguishable only because of the clear coincidence of modern field boundary with the limits of the high density scatter ... We chose to regard the landscape at Shapwick as a more-or-less continuous carpet of cultural material, in many cases displaced from their original place of use by human activity"*
> (Gerrard et al. 2007: 143).

Worn and abraded sherds cover much of the Near Eastern landscape. Some view them as “annoying “background noise” ”, but to others they are the archaeological evidence of an on-going continuum of human activity, dating back millennia (Wilkinson 1989: 31). Appropriate sampling techniques can be used to detect higher concentrations of sherds which may represent occupation sites, rather than general human activity in the landscape. Around the periphery of larger sites the sherd concentration may increase, demonstrating the manuring of fields around settlements (Wilkinson 1982; 1989). Sites where this is the case in the Near East are often visible, well-defined mounds - the remains of ancient mud-brick settlements. If this clarity is available, it is possible to make a clear distinction between ‘sites’ and ‘off-site remains’, although the boundaries are often indistinct and whether fields are included is variable. Others have attempted to define sites by the size of the increased intensity scatter, with arbitrary cut-off points determining significance and site type (Bintliff and Snodgrass 1988; Bintliff 2000; Wagstaff 1991). However, it was also shown that given the substantial quantity of sherds in the soil, some may form into more intense clusters completely by accident, and could be identified as ‘sites’, and that density is, in part, a factor of visibility. Nor is a ‘site’, necessarily defined as a place where human activity occurred, the same as a settlement (Schofield 1991).

The number of ‘sites’ in an area has obvious implications for studies of settlement patterning. These issues were extensively explored in a series of volumes on the Mediterranean landscape (Bintliff et al. 1999; Francovich et al. 2000; Gillings et al. 1999; Leveau and Populus Project 1999; Pasquinucci et al. 2000). That landscape has many similarities with the landscape of the Middle East: sherd scatters are ubiquitous, and ‘sites’ are often defined by sherd density. The volumes also specifically examined the effects of ploughing damage on sites (Francovich et al. 2000; and particularly see Hurtado 2000; Mattingly 2000; Taylor 2000; Terrenato 2000), which will be returned to in Chapter 3.

Even if distinct sites can be clearly defined, the nature of occupation in the area adds further complexity. Pre-Iron Age settlements (particularly mud-brick settlements) are often located on the remains of older settlements. Over time these towns and villages grow in height, forming tells which rise out of the landscape (for example, Tell Brak in Figure 2-1). These tells are common across the Near East and there are a large number in both surveys.

FIGURE 2-1: TELL BRAK (JULY 2010)[1]

Different parts of the mounds were occupied at different times. In many cases settlements were built over the ruins of older ones, so sites grew higher, although different parts grew at different rates. Over time, as the buildings degraded, 'peaks' could form on the mound representing different periods of occupation. Other new settlements expanded the mound, or were built nearby, eventually degrading and forming new mounds. Late Chalcolithic settlement was recorded around the main mound of Tell Brak, for example, and the size of the mound fluctuated in different periods. It began as spatially discrete settlement zones, which grew into a 130 hectare city. Other phases varied between 70 hectares, 45 hectares, and - in its final phase - a 14 hectare Abbasid town (Ur et al. 2011). These fluctuations within a single site sometimes led to multiple mounds which were recorded as a single 'site' in surveys. In areas where the surrounding ground level has risen, a single site with multiple peaks could appear as a complex of separate mounds, as the main mound became buried. The classification of a group of mounds into a single site is usually based on their proximity and discovery together during fieldwork, rather than a contemporary date or post-fieldwork analysis.

The clustering of mounds and how they are interpreted is clearly illustrated by an example from a case study - Tell Beydar Site (TBS) 29. The site consists of two distinctive mounds – A, a tell with a bulldozed lower town, and B, a large crescentic mound to the south east. Figure 2-2 shows the site on the survey sketch map, and Figure 2-3 shows the site on imagery. Also drawn on the sketch map is the outline of

[1] Photo copyright: the author

another mound to the west of B. Without excavation, the relationship between A and B is unknown. TBS 30 is listed as a separate site, but as can be seen from the imagery, is located very near A and B. There are other sites in the surveys where a mound which is located as near to 29 as 30 is has been counted as a part of the same site. TBS 40 demonstrates the other extent of the problem – numerous individual mounds are identified on the field sketch map (Figure 2-4) and visible on the imagery (Figure 2-5), but at least areas A and B are part of the same mounding as the tell (parts F, G and H). Two further unnumbered mounds are also sketched. It is very unclear what constitutes a separate 'site': this is deliberate. It was never the intention to accurately define coherent 'sites' in the field. Instead the lettered subdivisions were made in order to ensure that representative pottery collections were made from across the entire site area. The pottery collection areas allowed chronological sub-divisions to be estimated, which in turn enabled the area of the site occupied at any one time to be approximated (rather than assuming a mound was a single chronological unit). Settlements in this area continue to cluster around certain loci to this day, and even without excavation some relationship between the site areas seems likely.

In some cases even seemingly obvious discreet mounds are revealed to be natural when a section is cut through them. At TBS 7, for example, the field notes (1997) state

> *"Low rounded mound … Section which cuts this mound shows quite clearly that the mound is not cultural material, but is natural. The reddish soil of mound surface has a moderately sparse scatter of pottery and occasional flint. The site appears to be a Halaf site, now entirely eroded…"*

Most surveyed sites have not been excavated, and it was only rare sites which have been cut into by modern activity. This ambiguous definition is further complicated by the fact that as well as the obvious loci of human activities, numerous off-site features remain, such as quarries, roads, irrigation systems, and fields.

One final complication in site definition is a result of the nature of imagery. It is usually assumed (not incorrectly) that the area of the site as defined in the field approximates to the actual extent of the site. As will be shown in the ensuing discussions, there are a large number of factors which can alter the visible form of a site, not including those affecting site interpretations on imagery, which will be discussed in Methodology Chapter 4.4.

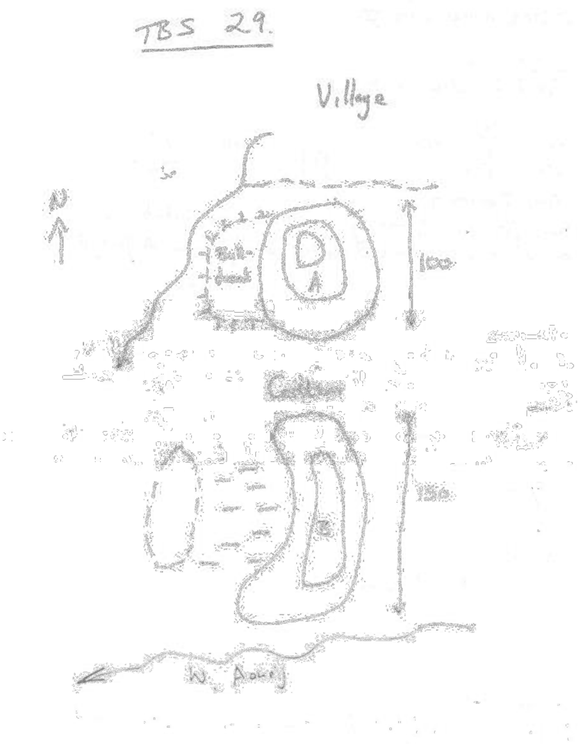

FIGURE 2-2: SKETCH MAP OF TBS 29 A AND B

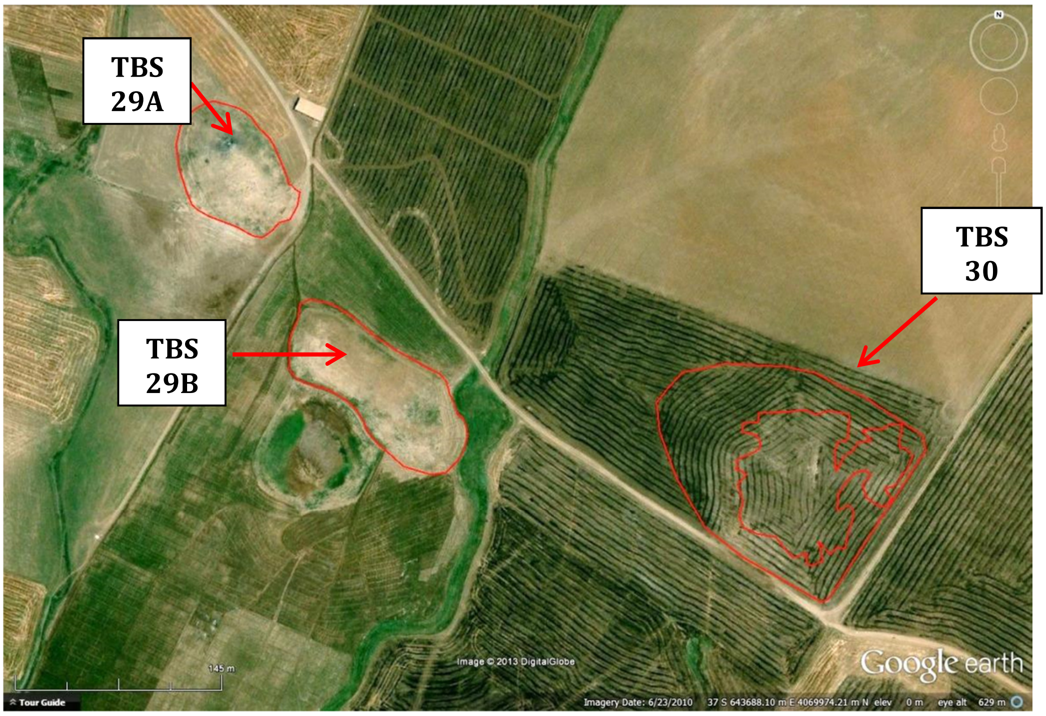

FIGURE 2-3: TBS 29, A AND B, (LEFT AND CENTRE) AND TBS 30 (RIGHT)[2]

[2] Geoeye Image, 23 June 2010. Taken from Google Earth 11 September 2012 (Contrast enhanced)

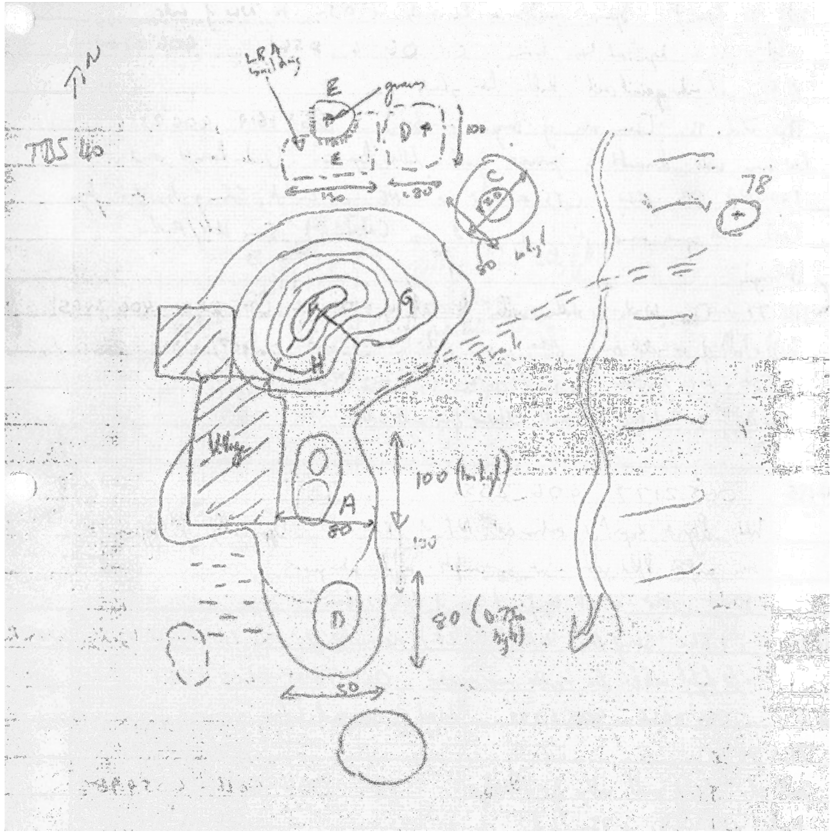

FIGURE 2-4: SKETCH MAP OF TBS 40

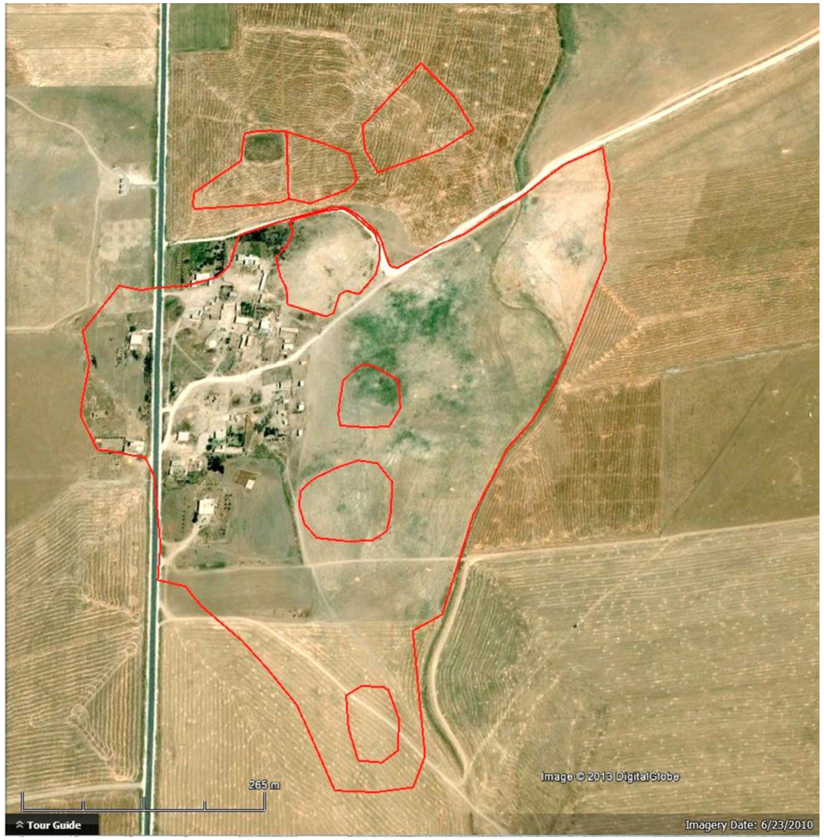

FIGURE 2-5: TBS 40 ON SATELLITE IMAGERY[3]

[3] Geoeye Image, 23 June 2010. Taken from Google Earth 11 September 2012 (Contrast enhanced)

Some sites appear larger on imagery than recorded during the survey, whilst others seem smaller. Work undertaken by Philip et al. (2012) demonstrated that interpretations of site boundaries based on satellite imagery can vary depending on the image type and resolution, the imagery enhancement method applied (for example, a standard deviation or histogram equalise stretch applied in GIS), the year, the season, and other environmental factors. Several sites were examined on a variety of images with different enhancements applied – no boundaries were drawn the same. When the sites were examined in the field, pottery collections were carried out which were assumed to equate with the outmost boundary of the site. In all cases, the site boundary estimated from pottery collection was smaller than the any of the boundaries drawn around the feature visible on imagery. These discrepancies can be caused by multiple factors, such as site erosion over time (elaborated in Chapters 3 and 4), seasonality, or even new cultivation which may degrade sites or bring them to the surface, altering their appearance. Apparent extensions to sites have not been included in the analysis: however, they are worth noting. If they are later confirmed as the remains of human activity, the damage to the site could be more extensive than recorded.

TBS 24, for example, was described as a "rounded mound with steep north slope", and the dimensions were 80m N-S, 70m E-W and a height of approximately 2m, as shown on the sketch map (Figure 2-6). However, early Corona imagery (Figure 2-7), taken before the increase in modern intensive agriculture, suggests that the true extent of the site is either much larger, or that the site has experienced extensive erosion (or both). All later sets of imagery also imply that the site extends beyond the initial assessment (Figure 2-8, Figure 2-9, Figure 2-10). Figure 2-11 shows the possible extents of the site according to the different images. If the site were larger than surveyed, then the tarmac road passing through it would have caused substantial damage, as would the ploughing. The full extent may never be known, which has implications for comparison of settlement patterns in the area. However, assessments of damage using satellite imagery techniques may provide a glimpse into sites or parts of sites that are now lost. If the extent is incorrectly estimated then it follows that all subsequent statistics based upon site area could be wrong. This question will be revisited in the Methodology Chapter 4.8.5 (p152), and in the individual case studies, where the impact of damage on sites is evaluated.

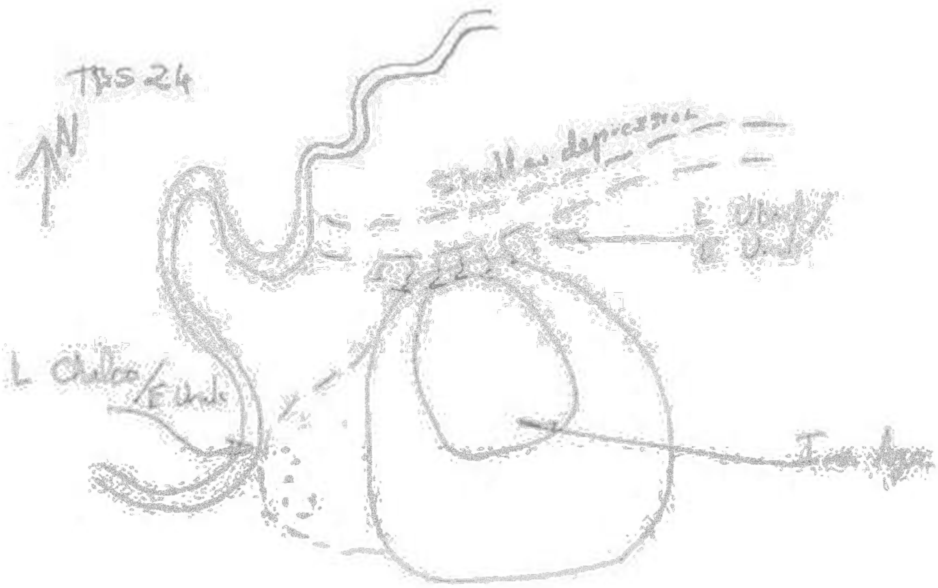

FIGURE 2-6: SKETCH MAP FROM FIELD NOTES OF TBS 24 (1997)

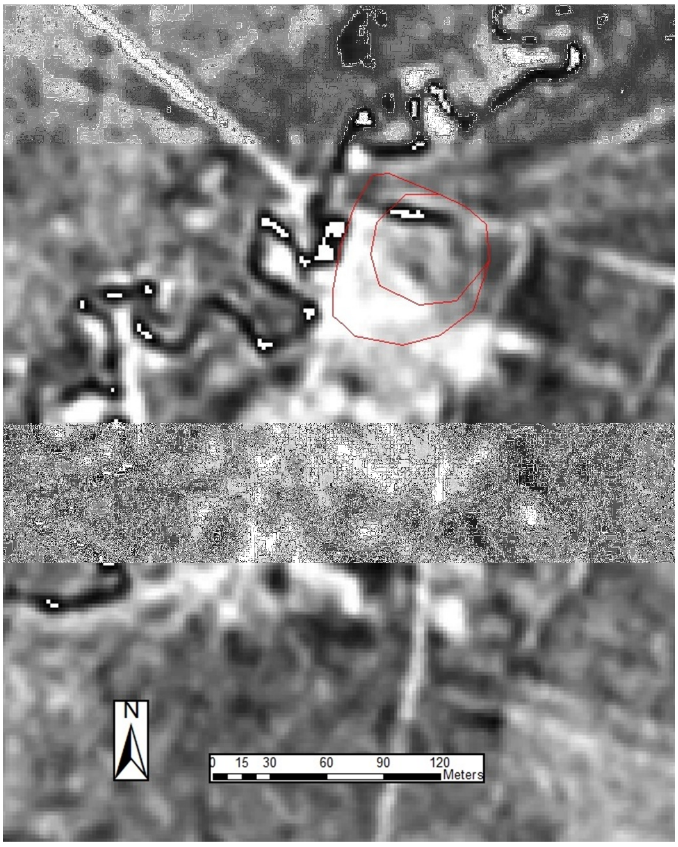

FIGURE 2-7: TBS 24 ON CORONA[4]

[4] Corona Image, 1105-1025df057-6_37N, standard deviation stretch, 03 November 1968

FIGURE 2-8: TBS 24 ON SPOT

Site (as identified in field visit)

Possible extent of the site

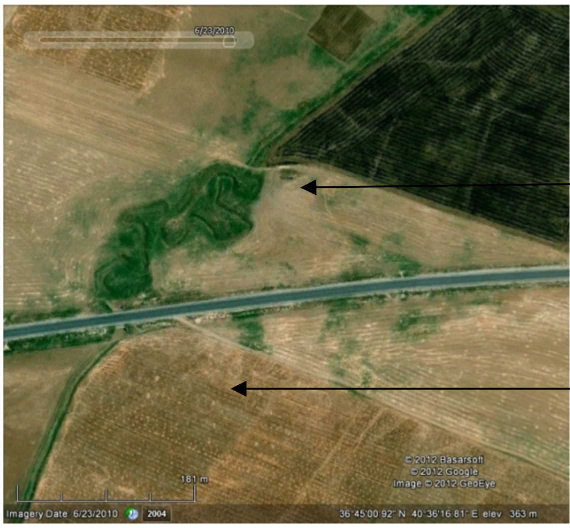

FIGURE 2-9: TBS 24 ON JUNE GEOEYE

Site (as identified in field visit)

Disrupted plough lines

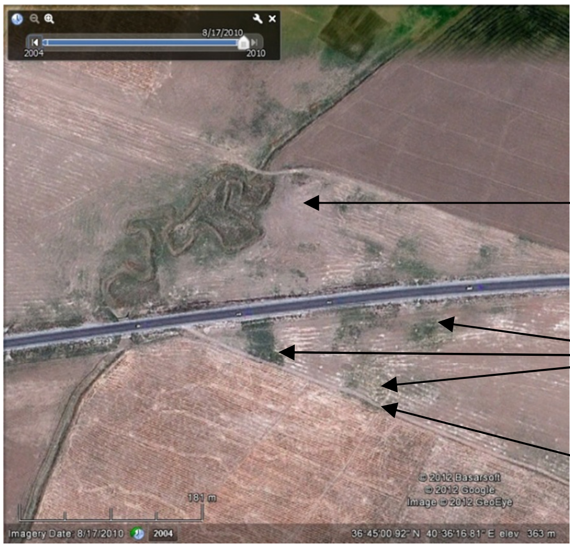

FIGURE 2-10: TBS 24 ON AUGUST GEOEYE[5]

Site (as identified in field visit)

Areas of heavy moisture retention (often associated with mudbrick)

Track going over a raised area

[5] Top: SPOT Image, 31 December 2004 (?). Middle: Geoeye Image, 23 June 2010. Bottom: Geoeye Image, 17 August 2010. Taken from Google Earth 20 April 2012

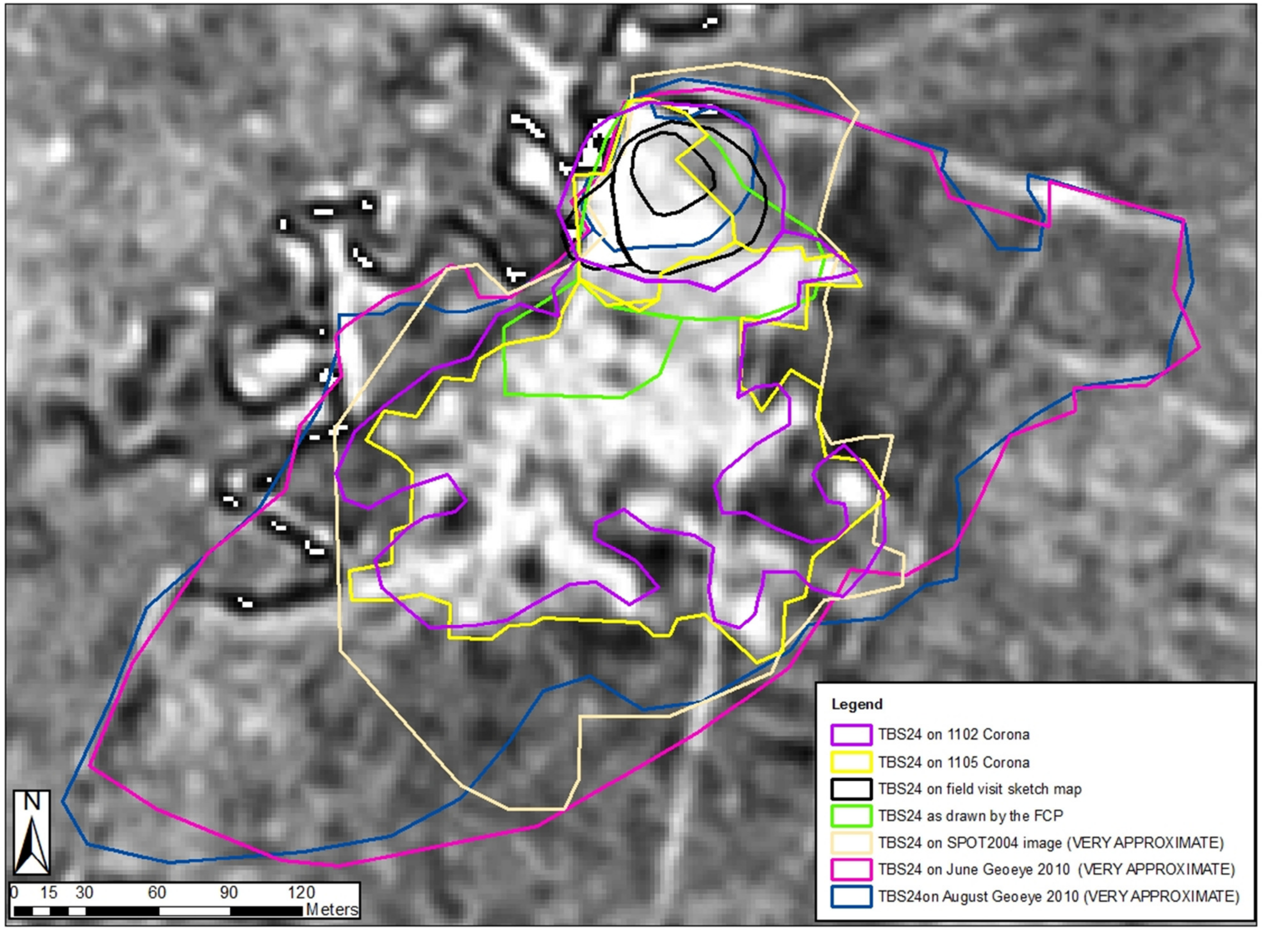

FIGURE 2-11: BOUNDARIES FOR TBS 24, ACCORDING TO DIFFERENT SATELLITE IMAGES

The background is Corona 1105 (November 1968). (Note – the boundaries from SPOT and Geoeye imagery are very tenuous)

Given the levels of complexity involved in defining and evaluating 'sites', in this study sites are defined as they were drawn in the field visit notes. Large tells, no matter how many collection units they are divided into, are counted as a single unit. Otherwise, if a mound has an alphabetic letter ascribed to it in a survey, it is counted as an individual unit. Mounds which are drawn on, but unnumbered, such as the two to the south of TBS 40 (Figure 2-4), are counted and given an identifier, as they were drawn during the field visit. These mounds were drawn as they were visible but constraints encountered meant they could not be visited. Sites can also be considered not just in terms of the number of component units, but in terms of 'site types' – the numbers of tells in the landscape or low mound complexes, for example. The way this is dealt with, expanded definitions, and the effect it has on the analysis are covered in Methodology Chapter 4.8.1, p163.

2.3 – The Scope of the Study - The Fragile Crescent Project

2.3.1 – Introduction

This study sits within the Fragile Crescent Project (FCP), based at Durham University, which aims to chart the rise and fall of Bronze Age settlement within the Fertile Crescent in a way that is comparable with the 'heartland' of urban development in southern Mesopotamia. The survey area extends from Mosul in Iraq westwards to the Mediterranean Sea, including parts of south-eastern Turkey, and southwards to Homs[6], covering an area of 700 x 500km (Figure 2-12) (Fragile Crescent Project 2010; Galiatsatos et al. 2009).

The project brought together data drawn from archaeological surveys, including digitised maps, aerial photographs, and satellite imagery into one analytical framework to provide a comprehensive, comparative data source, supplemented by publications from non-FCP surveys conducted in the area. The scale of study necessitated a large GIS framework, utilising digital terrain models, and site and feature locations and outlines. Arc 9.1, 9.2, 9.3 and 10 have all been used in this study. This has allowed analysis on both a local and a regional scale with an unprecedented level of detail. The datasets utilised owe a great deal not only to those who conducted the original surveys,

[6] Data from the southern part of this 'arc' has been obtained through Philip's project The Vanishing Landscape of Syria, funded by the Leverhulme Trust.
Philip, G. and Dunford, R. 2013. *Research Projects. Vanishing Landscape of Syria: Ground and Space Mapping of a Diverse World* [Online]. Durham: Durham University. Available: http://www.dur.ac.uk/archaeology/research/projects/?mode=project&id=362 [Accessed 17 April 2013].

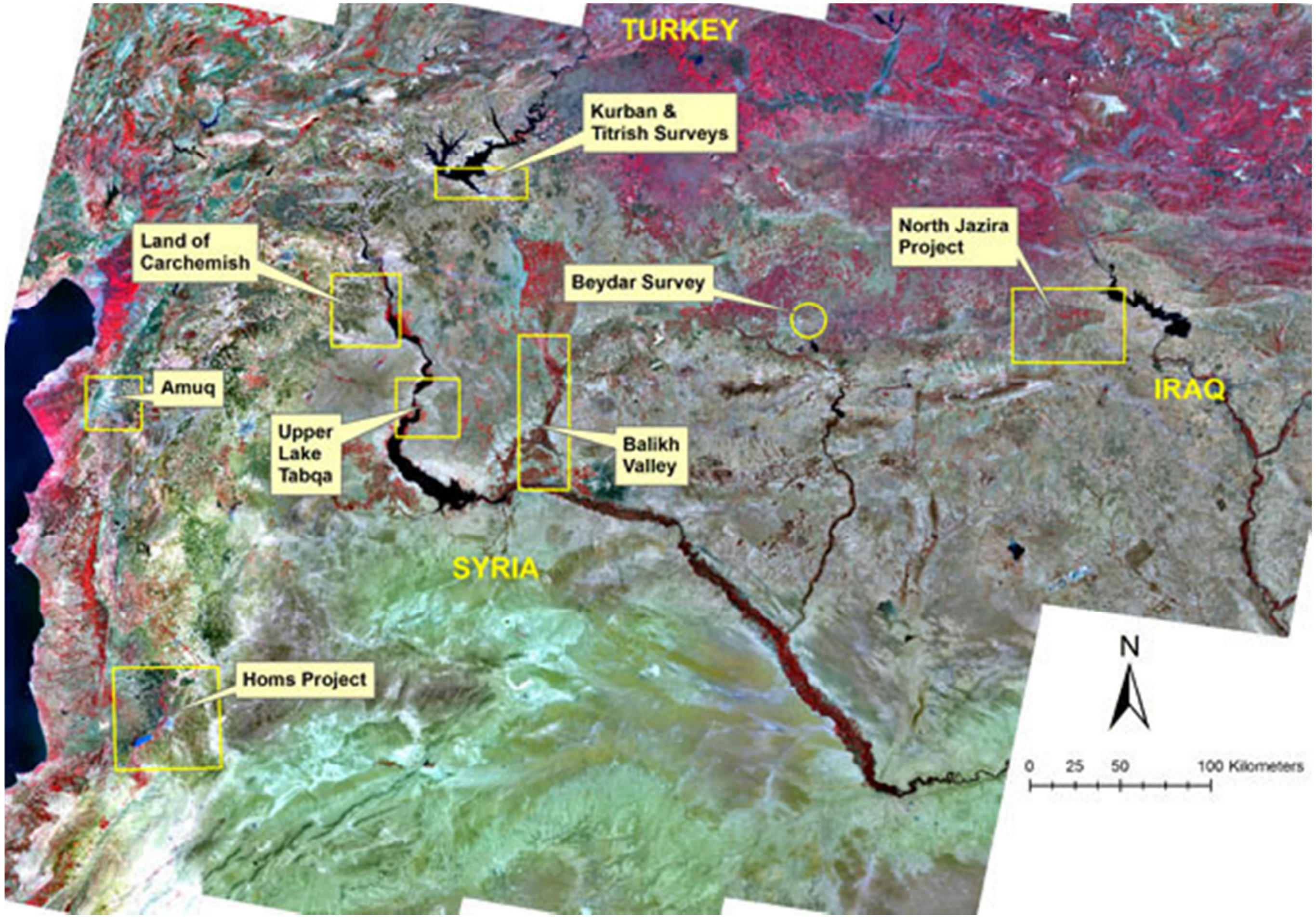

FIGURE 2-12: LANDSAT FALSE COLOUR MOSAIC OF THE FRAGILE CRESCENT STUDY AREA SHOWING THE APPROXIMATE LOCATION OF THE COMPONENT SURVEYS

(Map by Dr Galiatsatos, Durham University. False colour mosaic – bands 4, 3, 2) but also to the members of the Fragile Crescent Project who have worked on them. However, there are many challenges in combining data from different studies, done in different timeframes with different technologies (detailed by Lawrence 2012: Chapter 3, and discussed briefly in Methodology Chapter 4).

A particular goal of the study was to move away from the 'tell-focused' archaeology that has been the traditional practice in the area, and to record small sites and landscape features, as well as major settlements. However, landscape change is also central to the Project: without understanding what is lost, what remains cannot be interpreted correctly. Part of the Project description states:

> *"This will also give us the chance to detect changes in the landscape and thus identify archaeological landscapes of destruction and survival in the area of interest" (Fragile Crescent Project 2010).*

This idea of landscape change and how it relates to site damage, and the preliminary data collected on it by the FCP, underpins this thesis. However, my research is not a landscape study in the traditional sense (although that term is itself often contested – see Wilkinson 2003, Chapter 1 for a summary of definitions and approaches). My goal is not to record and interpret the cultural, social, economic, and symbolic factors that imbue and have modified the landscape over millennia, as is more commonly undertaken. Instead, whilst understanding the influences of the past, my own research focuses almost entirely on the present (although it is clearly founded on and structured by earlier, more archaeological, landscape surveys). The primary aim is to study the anthropogenic factors which have caused damage sites over the last fifty years in order to develop principles of site protection. In order to understand the causes of the damage to sites and extrapolate it beyond the survey areas, it is necessary to understand:

1. what sites are present, and to the extent to which those sites are representative of the wider area;
2. the geographic and environmental context of the sites, and the extent to which this context may have affected site distribution, and the present form of identified sites;
3. the historical context of the sites, and the extent to which historic anthropogenic factors have affected distribution and form.

The data collected by the FCP provides the essential foundation on which to base this study. Numerous sites have been identified and surveyed, and relevant information has been synthesised on a local and a regional scale. The survey information can then be used to inform the interpretation of the new data collected on site condition, and acts as a benchmark against which to assess changes over time.

The following sections therefore provide a brief, selective overview of the relevant physical geography, environmental factors and history of Syria as pertaining to site damage in the case study areas: a more detailed localised summary for each case study then follows. This overview is intended to provide context to a framework within which cultural and natural taphonomic factors affecting archaeological sites can be considered, rather than providing a comprehensive study. Thus the history of settlement is relevant not only in that it details the creation of the sites under study, but also because later settlement and its associated effects may have damaged earlier sites. No true historic population counts are possible, although some early censuses and tax records can give estimates (see Kennedy 2006 for an exploration of the issues). Pastoralist populations are particularly difficult to identify and enumerate, despite their prominent occurrence in some early textual records from the 2nd millennium BC onwards (Porter 2004; Porter 2012; Ur and Hammer 2009). Instead settlement is used as a proxy for intensity of occupation, cultivation and overall landscape impact. The longer the history of settlement in an area, and the more intensive the occupation, the more likely sites are to have undergone cultural, rather than natural, change.

2.3.2 – Geography, Environment and Climate of Syria

The area under study by the Fragile Crescent Project contains a broad environmental spectrum, including deserts, mountains, and fertile farmlands. As the area also spans several political boundaries, and includes parts of Syria, Turkey and Iraq, it was considered best to limit the study to one country. This means that sites have been subject to the same site protection policies. A more in-depth study of fewer areas will reveal more information than a broader geographical study of the region. After careful consideration, only two case studies were chosen, both in Syria.

Syria is composed of mountain chains running north-south, paralleling the western coast of Syria and Lebanon, forming important sources of ores and minerals, whilst the rivers which drain from them water fertile agricultural areas. Between the mountain chains are plateaus, and agriculturally important river valleys and basins, many of which form part of the Tigris-Euphrates river system. Northern Syria and Iraq, from the Euphrates to the Tigris, form the Upper Mesopotamian plain known as the Jazirah, which extends north into Turkey to the base of the Taurus Mountains. Settlement was, and still is, clustered along the coast, the lower, wetter mountainous areas, numerous extensive basins (such as the Upper Khabur and Upper Balikh basins) and along the river valleys.

Environmental factors such as soil fertility and rainfall potentially impact on settlement density and land use intensity, both of which play a major part in cultural taphonomic processes. During the Mid-Holocene, data suggests that the area was wetter and more verdant, but this was probably followed by wide-spread multi-century climatic deterioration, which peaked about 6,200BC. However, such data cannot usually be generalised to any distance, so local climatic effects cannot be accounted for. In general, rainfall levels and aridity have continued to fluctuate. Relatively recently, for example, climatic variability and increasing aridity is thought to have been a contributing factor in the Mongol invasions of the 13th century (Hole 2006; Kuzucuoğlu 2007; Robinson et al. 2006; Wossink 2009). In general, these climatic trends mirror expansions and reductions in settlement, although they are unlikely to have been the sole cause. Around the time of each climatic change, settlement retracted, only gradually returning to formerly inhabited areas. Some areas of the Near East have recently undergone a brief but serious drought from 2007-2009 (Trigo et al. 2010), which has led to a retraction in settlement as people have left the farmland for cities.

The current climate (summarised from Akkermans and Schwartz (2003) and Wilkinson (2003)) is characterised by dry, hot summers and cool, rainy winters, with extensive regional variability. The north consists of extensive agricultural plains which are suitable for dry-farming. Due to the variability of the rainfall further south, irrigation becomes essential for agriculture. Eventually agriculture becomes impossible and the land is only good for grazing. This is demonstrated on Figure 2-13, an extract from the TAVO Atlas showing land use in Syria, with the case study areas marked. Carchemish is on the border between an area of scattered irrigated land and no irrigated land. Tell Beydar is in an area without irrigated land, although just to the south, at the junction of the Khabur and the Wadi 'Awaidj, there is scattered irrigated land. However, this map predates the building of the West Hasseke Dam: land use today is almost certainly somewhat different, as will be demonstrated in Chapter 6.5 – Land Use (p207).

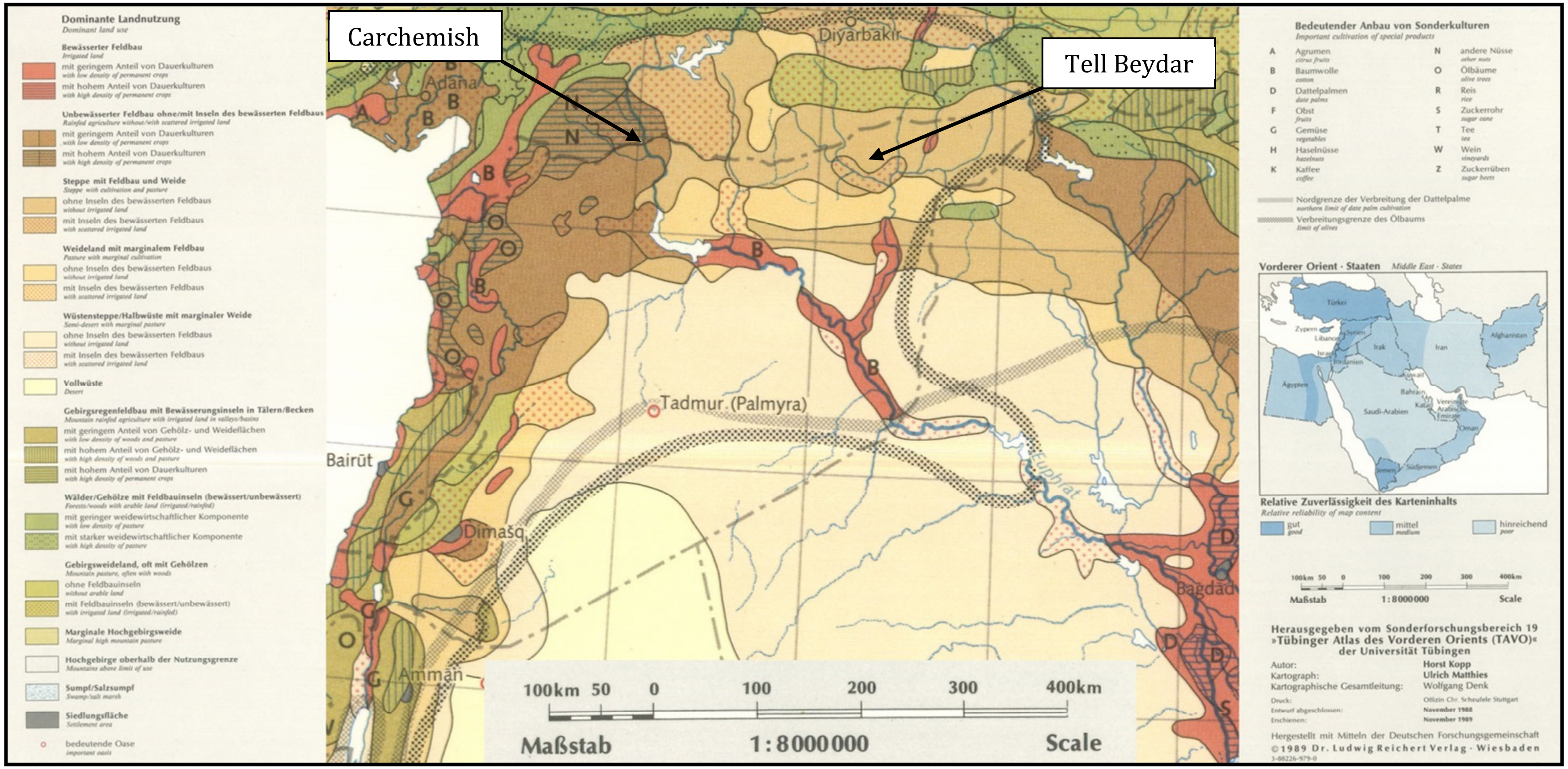

FIGURE 2-13: LAND USE IN SYRIA IN 1989[7]

[7] Extract from Map AX1: Middle East Land Use, showing Syria. Tubinger Atlas Des Vorderen Orients (TAVO), copyright 1989. Mittmann, S. and Schmitt, G. 2001. *Tübinger Bibelatlas : Auf Der Grundlage Des Tübinger Atlas Des Vorderen Orients (Tavo)*. Stuttgart: Deutsche Bibelgesellschaft.

The small coastal plain receives an average of 600-1,000mm of rainfall per annum, but the eastern plains are much drier. The Syrian steppe receives between 200-400mm of rainfall, with rainfall increasing further north. It should be noted that the rainfall levels are not static, and droughts are frequent across many parts of the Fertile Crescent, as are high levels of inter-annual and decadal variability (Trigo et al. 2010: 1245). The following map (Figure 2-14) shows the current 200-300mm rainfall isohyet boundary in Syria: north of that boundary rain fed agriculture is possible most years. With irrigation, agriculture is almost always possible, becoming more consistently so moving further north. Within the 200-300mm boundary is the so-called "Zone of Uncertainty" where agriculture is possible in wet years, but the land is often used for grazing.

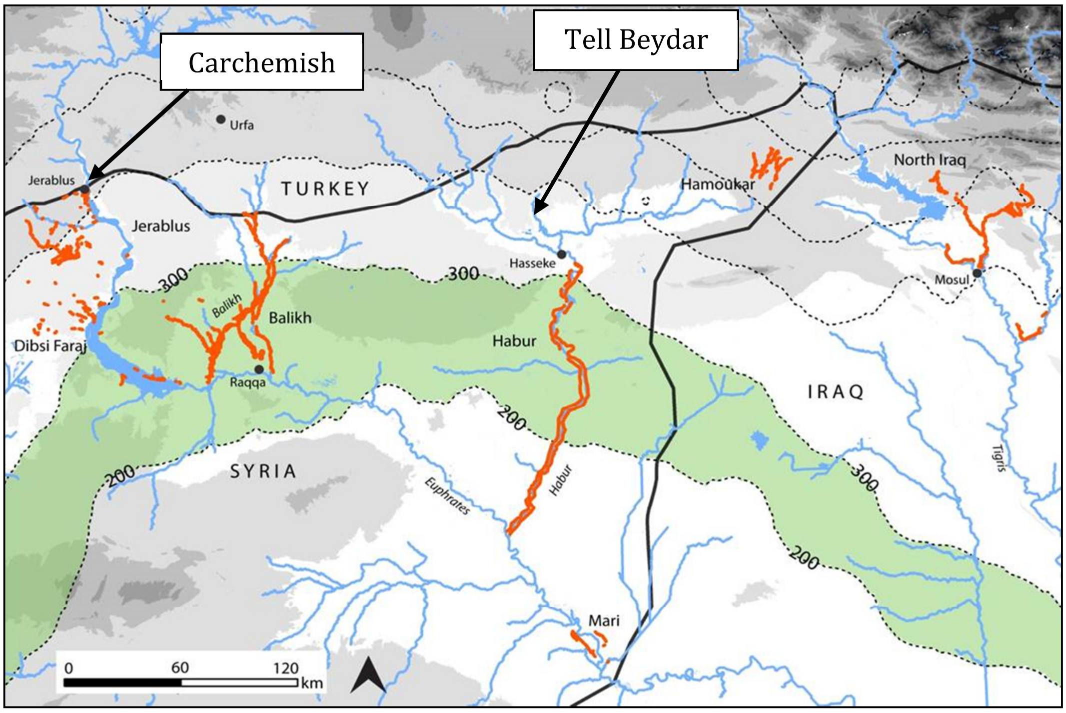

FIGURE 2-14: RAINFALL MAP OF SYRIA[8]

2.3.3 – BRIEF SETTLEMENT HISTORY OF SYRIA

Early Settlement

11,000 years ago (the end of the Younger Dryas), the area was populated only by small bands of hunters but by c. 8,000 years ago, an economy of agriculture and livestock had fuelled the spread of settlements. However, early occupation left only slight, fragile traces with little depth in the landscape.

[8] Map by Louise Rayne, Durham University. Rainfall data is from the German Federal Ministry of Transport, Building and Urban Affairs, using the GPCC Visualiser: http://kunden.dwd.de/GPCC/Visualizer

In the Neolithic, settlement patterns appear to have shifted between fully sedentary agriculturalism and fully nomadic pastoralism. Very few sedentary Neolithic settlements remain today and even less evidence of the transitory nomadic lifestyle, destroyed by the same natural taphonomic processes affecting all sites. However the contribution of the larger complex settlements which were to follow must also be acknowledged.

Irrigation - in the form of major canals - is known elsewhere from the 6th millennium BC, expanding the possibilities for cultivation, and allowing people to settle in more climatically variable areas, although there is little evidence for this in Syria. In the 4th millennium BC, the invention of the ox-drawn plough enabled further expansion of cultivation. There is definite evidence of irrigation by the 3rd millennium BC, and the amount of irrigation in the north increased somewhat in the 2nd millennium BC, and significantly more after 1000 BC (Wilkinson and Rayne 2010). Cultures maintained a shifting spectrum between settled agriculturalism and nomadic pastoralism as a way of adapting to the climatic variability (Turner et al. 1977), but in periods of population increase, agricultural intensity increased and new ground was broken, adding to, but also over-writing earlier occupation traces in the landscape. Even the comparatively superficial early ploughs will have damaged the shallow sites left by early hunter-gatherers; the breaking of new ground made it more susceptible to erosion (Hole 2006); and the early canals were only slightly less damaging than their modern counterparts, albeit on a smaller scale. Smaller settlements were gradually abandoned, and nucleated cities became common.

Complex societies emerged and developed into competing city states, and then into competing polities and later empires. These included the Akkadian, Mitannian, Hittite, Egyptian and Assyrian Empires, and subsequently the Neo-Assyrian and Neo-Babylonians amongst others. (For details, see Akkermans and Schwarz 2003). It was these early states who built the cities which would become the large Bronze Age tells which cover the Middle Eastern Landscape. Cities had control of large agricultural hinterlands, demonstrated by radial routes around cities to the fields, as well as areas to graze large flocks. A network of roads connected them to the villages as well as distant trading opportunities. Remarkable preservation in the Jazirah allowed the mapping of these 4,000 and 5,000 year old roads on 1960s Corona imagery (Menze and Ur 2012; Ur 2003; 2010b; Wilkinson 2000; Wilkinson et al. 2010), hinting at the true extent of population interaction across the area. This extensive landscape utilisation was also intensive: cities were built over older settlements, continuing a process that began thousands of years previously and continues to this day. At best this process hides early settlements; at worst it destroys them. In the most intensely settled areas, where all resources were exploited, fragile nomadic sites and other early occupation traces will have been similarly overridden, except in areas of exceptional preservation, or where features continued to be reused.

These empires continued to wax and wane until Alexander conquered most of Syria in the 4th Century BC, extending the Hellenistic world. In 64BC it became part of Rome, but parts of Syria continued to be conquered and reconquered by eastern empires for several centuries. Under Greece and particularly under Rome, Syria's agricultural potential was utilised to supply the western empires. New village settlements were founded in both new locations and on and around the old tell sites, and small Roman farmsteads dotted the landscape. In the 4th century in particular, the population noticeably expanded. However, by the 7th century AD, Persian invasions had closed the Mediterranean to Syria, and in AD 637, Syria was largely conquered by the Muslims: the Omayyad Caliphs chose Damascus as their capital, and Syria became the centre of the Islamic world, although parts continued to change hands. However, the years of intensive agriculture took their toll, leading to soil exhaustion, the loss of ground cover and consequent soil erosion. It was not until after the expansion of Islam that the population began to increase again in the 8th-9th century (Ball 2000).

The 11th-13th centuries saw repeated invasions and conflict between the Crusaders, the Mongols and the Seljuk Turks. This may have led to the abandonment of much of northern Syria but some places names in the Khabur Basin survived from the Islamic Middle Ages through to the 16th century, implying continuity of settlement (Hütteroth 1992).

By the 16th century AD, Syria and Iraq were under Ottoman control (İnalcık 1978; 1993; 1995; 2000; 2006; İnalcık and Quataert 2004). Studies of Ottoman tax records (Göyünç and Hütteroth 1997; Hütteroth 1990; 1992; Hütteroth and Abdulfattah 1977) show a rising population and increasing land shortage in the mid-16th century. Cultivation and settlement extended to the 250mm isohyet – a frontier it was not to reach again until the 1950s.

Famines in the 16th -19th century caused mass migrations and depopulation: attacks by Bedouin tribes from the Syrian steppe and unemployed mercenary troops decimated large cultivated areas (İnalcık and Quataert 2004). This led to a notable settlement decrease, particularly in areas by the Bedu frontier, and by the 19th century many parts of Syria were largely abandoned (Hütteroth 1992; Hütteroth and Abdulfattah 1977; İnalcık and Quataert 2004; Lewis 1955).

It is conservatively estimated that (excluding the Jazirah) from the 1850s to the beginning of World War 1,100,000 square miles of new land were brought under cultivation and ploughed, and 2,000 villages in Syria were created. Infrequently cultivated land was brought into regular cultivation; hamlets became villages (Lewis 1955). By the end of the 19th century, even the nomadic groups began to settle into more sedentary lifestyles. Wagstaff (1985) estimated that the population of Greater Syria increased from 1 million to 4 million people between 1800 and 1920.

Twentieth Century Resettlement

Although earlier phases of settlement created and later impacted on the archaeological record, the resettlement programs of the twentieth century have probably had the greatest effect on the present day pattern of site damage.

At the end of World War 1, Syria became a French Mandate and cultivation continued to extend into northeast Syria (Lewis 1955). Railroads began to connect the provinces and major cities to the outside world and new roads were built (Devlin 1983). Suddenly it was no longer only the coast which had easy opportunities for international trade and access to resources improved. A Syrian State was established in 1946, and gradually living conditions improved as electricity, education and healthcare became more widely available, with all the infrastructure that implies (Nyrop 1971). Figure 2-15 shows the development of settlement in Syria between 1800 and 1950. The Tell Beydar area was primarily settled after World War 1, whilst the Carchemish area was settled slightly earlier, mostly between 1850 and 1950, although it borders an area which was already well settled by then, and which had only a minor settlement density increase since the 19th century.

The land reform programme began the redistribution of land away from large landowners in the 1950s and 1960s (for more details see Perthes, 1995). Canals and reservoirs were planned and wells (not all of them licensed) were drilled to provide irrigation water for further agricultural expansion, particularly cotton. The government offered financial encouragement to increase cultivation: in 1962, roughly 62% of the population (c. 3 million people) practised agriculture, and only 5% were nomadic pastoralists. Farm machinery and diesel pumps also became available, and the steppe was opened to speculative cultivation (Hole 2006). The number of tractors

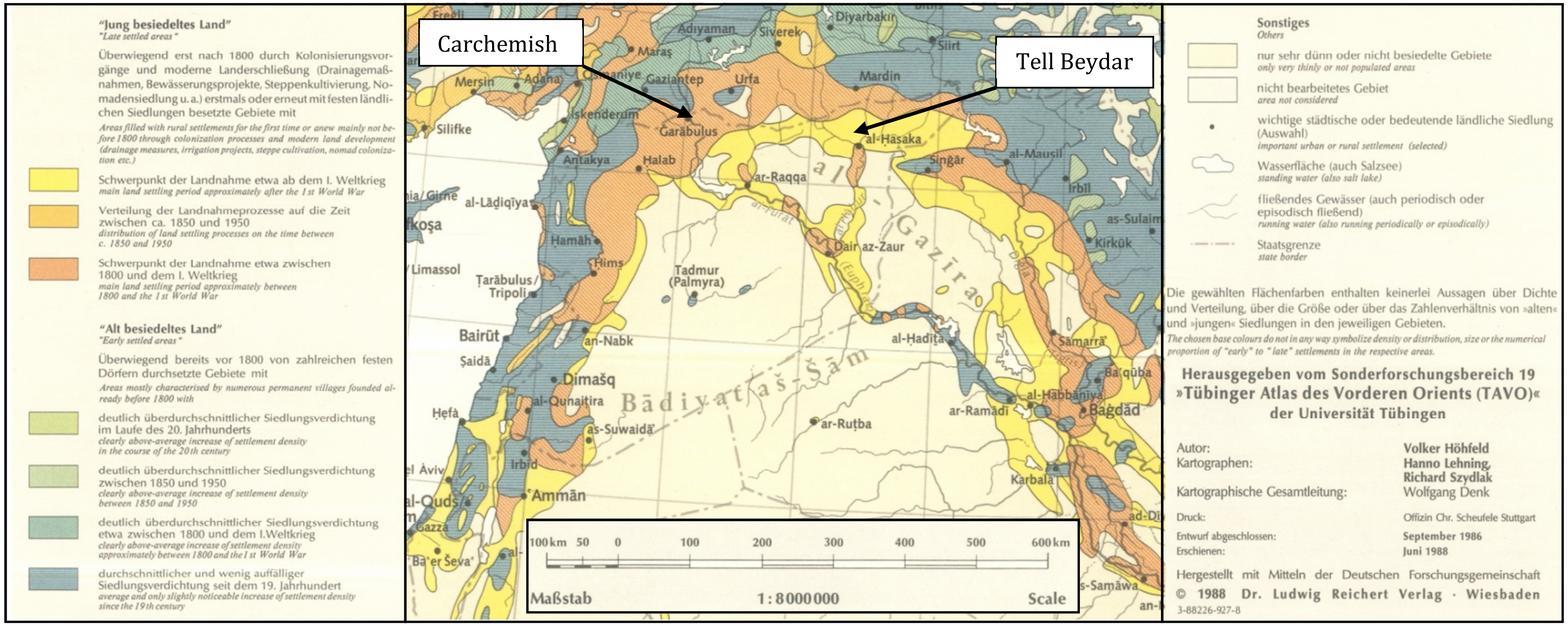

FIGURE 2-15: EARLY AND LATE SETTLED AREAS OF SYRIA (1800 – 1950)[9]

[9] Extract from Map AIX1: Middle East: Early and Late Settled Areas, showing Syria. Tubinger Atlas Des Vorderen Orients (TAVO), copyright 1989. Mittmann, S. and Schmitt, G. 2001. *Tübinger Bibelatlas : Auf Der Grundlage Des Tübinger Atlas Des Vorderen Orients (Tavo)*. Stuttgart: Deutsche Bibelgesellschaft.

increased from 3,300 in 1956 to 8,600 in 1962, with a comparable increase in threshing machines. Between 1947 and 1962 the number of irrigated acres also doubled. It was estimated that approximately 4.4 million acres of land was in cultivation before World War I. By 1945 it was estimated at 5.7 million acres, and by the early 1960s this had risen to 15.5 million acres, with another 4.5 million acres classed as arable land but not farmed.

Double cropping was standard - wheat and barley were grown in winter and cotton in the summer. This new cultivation zone extended 50 miles into the zone of uncertain rainfall (200-300mm). The unprecedented intensity also led to the loss of forage plants traditionally grazed by the Bedouin. As well as the loss of land, it increased the amount of time soil was exposed and therefore open to erosion (Nyrop 1971). Between 1970 and 1993 total cultivated land increased by 40%. Within that, irrigated land increased by 80% (Perthes 1995).

Today some 65% of Syria is considered arid or semi-arid. About half the land is steppe and only exploitable as pasture, although in total it is estimated that approximately 75% of the land is agricultural (FAO Statistics Division 2013; The World Bank Group 2009).

The United Nations Food and Agriculture Organization (FAO) estimated the total agricultural area in Syria was at its greatest in 1963, covering 15,041,000ha (82%) of a possible 18,378,000ha (since records began in 1961). In 2011, on the other hand, there were 13,941,000ha of agricultural land (75.5%)[10]. The total area equipped for irrigation across Syria, on the other hand, was 558,000ha in 1961 (3.0% of the total land area), and peaked in 2004 at 1,439,000ha (7.8% of the total land). The total area equipped for irrigation then dropped to 1,399,000ha in 2011 (7.6% of the total land), perhaps due to the drought and the drop in groundwater levels. These changes in the amount of land devoted to agricultural use and in land equipped for irrigation are demonstrated in Figure 2-16. This demonstrates that it is becoming increasingly necessary to irrigate agricultural land, even though overall agriculture is currently declining: this intensification over time will pose a greater threat to sites.

Despite the increase in irrigation, much agriculture is still rainfall dependent, particularly as the water table across Syria continues to drop (IFAD 2010; Perthes

[10] It should be noted that FAO statistics may differ to some other statistics due to the classification of 'bare' land / rangeland. This land is intermittently used for grazing, which affects its classification.

1995; The World Bank Group 2009). Syria has been in an official state of drought since 2006 according to the UN, FAO and World Food Programme: lack of water is becoming a serious problem (Irin and sb/at/cb 2010; Trigo et al. 2010).

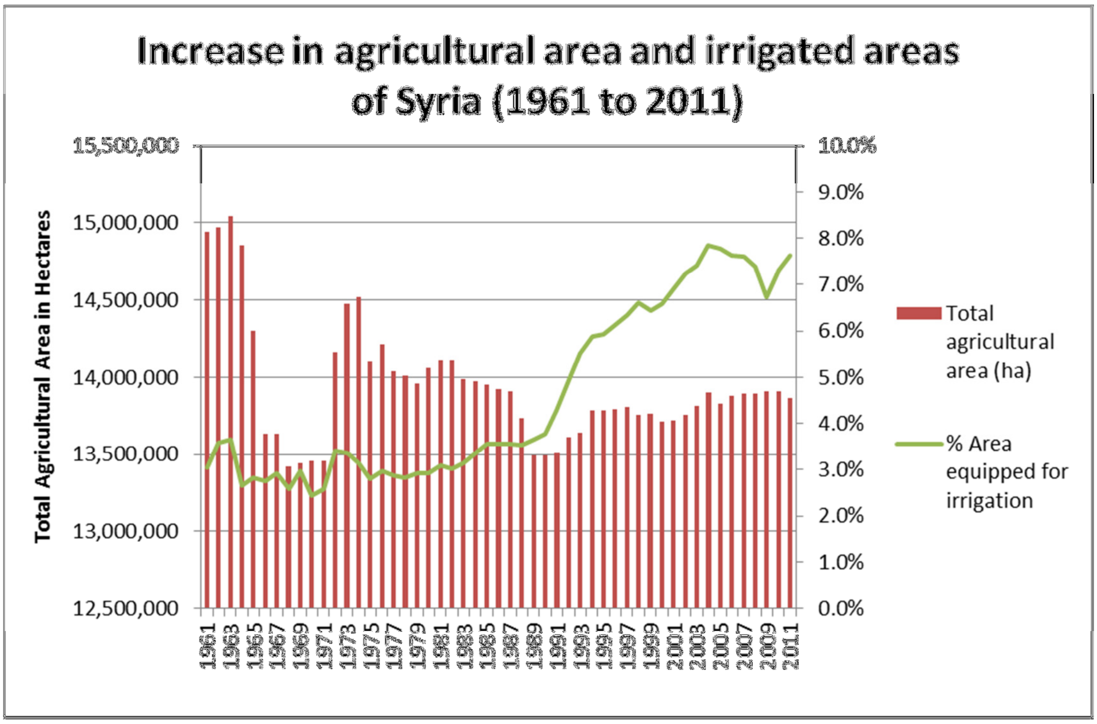

FIGURE 2-16: CHANGES IN AGRICULTURAL LAND AND IRRIGATED LAND (1961-2011) (FAO STATISTICS DIVISION 2013)

According to a UN reporter

> *"Water sources have also been permanently affected. Farmers used wells to draw on groundwater resources because of a lack of rainfall. The situation is exacerbated by the inefficient use of water …[he said] the dropping of groundwater tables was "a serious concern" "* (Irin and sb/at/cb 2010).

Syria's population is currently decreasing (IFAD 2008; 2010): total population density reached 115.5 people per km^2 in 2008, but dropped to 111.3 people per km^2 in 2010. The rural population makes up approximately 45% of the total population: this has dropped as people have abandoned their fields and moved to the cities to find work whilst the drought continues. The land that is still in use, however, is being used more intensively: the threat to sites from agriculture, grazing, irrigation and the desiccation of the ground are discussed in detail in the following Chapter.

This historical and environmental foundation is essential to understanding the context of the sites studied in this research, and the changes which have occurred to the archaeological record over the millennia. Without it, no distinction can be made between cultural and natural site transformations, and sites cannot be assessed in terms of damage or preservation.

2.4 – The Case Study Areas

From the surveys conducted by the Fragile Crescent Project, two case studies were chosen: the area around Tell Beydar in the Upper Khabur Basin on the edge of the Jazirah, and the area south of Carchemish by the River Euphrates on the Syrian/Turkish border (see Figure 2-12 for the survey locations). Together they contain 161 surveyed sites. Each case study area will only be discussed briefly here, in order to contextualise the following chapters. A detailed local description will preface the data analysis for each area, enabling a more nuanced, region-specific understanding of the damage occurring.

Each survey has provided detailed information on the sites in the form of GPS points, field visit notes and site sketch maps, as well as research which places these sites into a regional framework. The Tell Beydar area is an agricultural region with a long settlement history where periods of dense settlement are followed by relative abandonment. However, concentrated resettlement of the area post-1850 was followed by large-scale increases in cultivation and a general lowering of the water table, culminating in the building of the West Hasseke Dam. This has allowed even more intensive irrigated agriculture across the survey area, and as this was a secondary consequence of the dam, no rescue work was implemented in the newly-irrigated areas. The field visits were conducted after the dam was built: more than a decade has passed since. Over the elapsed time, the consequences of the dam's implementation on archaeological sites outside the reservoir area will have become visible and it is now possible to study them and compare them to the benchmark field visits. A full description of the case study area with maps of the sites, a geographical and environmental summary, a history of the area and an outline of the survey work undertaken is contained in Chapter 5.

The area south of Carchemish, on the other hand, has had a more mixed settlement history. Areas around the river banks have been (and still are) extremely fertile, and settlement there was (presumed to be) extensive. Multi-period tells, particularly the major city of Carchemish, demonstrate the early importance of the region, and intensive Roman settlement even in marginal areas testifies to the density of their occupation. After that, however, the area largely passes out of history, and whilst numerous small Islamic sites were recorded in the survey, the area does not appear to see the same population and cultivation peaks witnessed under the Ottomans in the 16th century and 19th century. The building of new dams along the Euphrates has returned focus to the region, as well obliterating large parts of the ancient flood plain. For the first time in almost 2,000 years, cultivation is extending again into marginal areas. This study will attempt to determine the effect. The contextual overview of the Land of Carchemish survey is given in Chapter 7, before the analysis of the area in Chapter 8.

2.5 – Concluding Remarks

The Fertile Crescent has a long history of settlement which has impacted the landscape both in terms of site creation and site removal. Millennia of natural processes have altered the shape of the land and the appearance of the sites upon it, whilst simultaneously affecting on-going settlement trends.

The extensive amount of data on the sites and the landscape collected by the Fragile Crescent Project provides a detailed backdrop against which to study the modern context of the sites. The nuanced understanding of the history of occupation of the different areas and their physical environments are essential to contextualising their condition.

The historical (and pre-historic) populations of Syria have left their mark on the landscape, creating the sites we study today, and in so doing have altered and erased the traces of those who went before them. There have been periods of intense occupation, most notably the Early Bronze Age, Roman, and early Ottoman landscapes. During these periods agriculture expanded and intensified, and settlements spread. Topsoil which protected sites was broken anew by the plough, and over time this - and the ensuing soil erosion - aided the degradation of older sites. Each of these periods was followed by settlement decline: the soil gradually reformed into protective layers over buried sites, and more recent settlements slowly began their transformation into archaeological sites. However, as destructive as each of these periods may have been (and we can never know for sure), the extensive population increase of the last hundred and fifty years, and ensuing development, infrastructure and agricultural expansion have unarguably caused far more damage. It is impossible to know the state of the land in 1850 compared to that seen on the 1960s Corona imagery, but even this brief précis of settlement history suggests that earlier damage is understated. Considerable damage from both cultural and natural causes (elaborated on in Chapter 3) may already have been done, and the remarkable preservation visible on Corona could already be only a fraction of what was present a hundred years previously. The Ottoman resettlement started a process of landscape change and site destruction which continues to accelerate to this day: this is demonstrated at a local level in the case study descriptions in Chapters 5 and 7.

Through comparison of these two very different areas of Syria, I aim to understand locally specific patterns of damage, and to draw out general trends which can be extrapolated to the wider region described in this Chapter. In order for that to be successful, it is necessary to understand what is meant by damage, under what conditions it occurs, and what impact it has on sites. The following chapter therefore discusses the concept of damage - how it is defined, what causes it, and what factors affect it, forming a vital element of the context of this study.

"To teach us that cities dye as well as men, it is at this day a cornfield, wherein the corn is grown up, one may observe the droughts of streets crossing one another"

~ William Camden (1551 – 1623) ~

Chapter 3:

Damage: Definitions and Types

3.1 - INTRODUCTION

It is a critical time in the archaeology of the Near East. Sites are being damaged, but there is inadequate information about the archaeological resource against which to judge the extent of the effects. New sites are being discovered all the time, often located because of the damage to them. This is coupled with an absence of quantified baseline data for predictive studies.

The study of damage is also hindered by a lack of definition. A site which has been 'damaged' may have been completely flattened by a bulldozer, or cracked by weathering, or painted with graffiti. Damage is an all-encompassing term, which makes study of the problem particularly hard. This chapter will examine how threats affect sites, as well as considering the other factors which affect the severity of damage, proposing new ways to consider the problem.

It is first necessary to discuss site formation processes, particularly those relating to tells, which are a common site type in the Near East, and which can represent millennia of occupation (such as Tell Jamilo (TBS 59), Figure 3-1). It is this longevity which makes them of particular interest: even once abandoned they persist as loci in the landscape, and are a focus for later occupation. Initial archaeological interest in the Near East concentrated on these large tell sites, and whilst the focus has widened, they are, in many ways, a microcosm of the issues underlying the cycle of site creation, abandonment and decline for all sites, and the impact this can have on archaeological study.

FIGURE 3-1: TELL JAMILO (TBS 59) IN JULY 2010[11]

This was eloquently summed up by Butzer and Freeman (1986: xiii - xiv)

> *"Tells contain a unique record of both human activities and environmental processes ... The constituent materials of a tell range from organic-cultural refuse, collapse rubbles [sic] of mudbrick and the like, to water and wind-laid beds. The rate and type of buildup differ on living floors, in streets and alleys, or in and around community structures, such as civic buildings, walls terraces, and drainage systems. Furthermore, during times of demographic expansion, construction in a village mound outweighs decay, so that garbage or collapse rubbles due to accident or selective razing show little net accumulation because they are cleared away and dumped elsewhere. But during times of progressive demographic decline or catastrophic destruction, through natural or human disasters, garbage and collapse rubbles build up and are then affected by running water, by biogenic agents, and by wind...*
>
> *Once abandoned the mound is slowly lowered by compaction and weathering, as well as by erosion through gravity movements, surface water, and wind; such sites may also be used as quarries for rock, mud, pottery temper, and fertilizing compounds; finally, shifting streams can undermine and erode a mound. As the topographic form is gradually flattened, potsherds move down-slope and initially concentrate around the lower periphery of a mound, where trampling reduces them in size; eventually the sherd debris is increasingly buried within water-laid sediments or turned down into the soil by plowing. Such insights can significantly aid in archaeological surveys ... and in interpreting the long-term settlement history recorded within a mound."*

When it comes to these surveys, and the accompanying interpretation, site damage is in many ways the ultimate irony for archaeologists. If sites were intact, left as they were at the time of abandonment, less study would be needed – settlement patterns would be far easier to see, for example. Once hidden and degraded by time, it is often the

[11] Photo copyright: the author

damage that sites experience that allows us to locate them, and to learn about them. As Camden, quoted at the start of this chapter, rightly observed more than 400 years ago, it is through agriculture we find the ghosts of cities, and thus their remains. Some authors (for example Dunnell and Simek 1995) have even gone so far as to suggest that tillage can be used as an investigation technique to reveal more about deposition structures. At the Syrian site of Carchemish, orchards have partially destroyed the upper levels of a large part of the lower town, and yet also preserved the remaining levels from utter destruction by the expansion of the nearby town. In their survey of the North Jazirah in Iraq, for example, Wilkinson and Tucker note that several of the sites they surveyed were cut by canals and drains, the presence of which "enabled the context of the scatters to be examined" (Wilkinson and Tucker 1995: 20), which would otherwise have been impossible due to permit restrictions.

This is not to say that site damage is always a good thing. It is an on-going process: eventually there comes a point in the lifecycle of a site where it is no longer of value to the archaeologists, when it is so damaged no useful information can be extracted. Older sites, for example, tend to be more poorly preserved, and therefore provide less information. However, the specific point is different for each site, and is dependent not only on the unique context of each site, but also on the time, money and resources available to the archaeologist.

Nonetheless, there are some generalities which can be applied to sites in the Near East, and specifically in Syria, regarding site damage. Site damage occurs as a result of a number of different sources, with different extents and effects. Each threat also has specific characteristics which are visible on satellite imagery. These threats, their impacts and their appearance, will be discussed in this chapter. However, in order to understand how damage to sites occurs, it is necessary to understand site formation and transformation processes, as well as the surrounding context.

3.2 - Landscape Formation and Transformation Processes

"Unless the genesis of deposits is understood, one cannot infer the behaviours of interest from artefact patterns in those deposits"
(Schiffer 1983: 675).

This point is equally valid to the study of sites: by the time they are surveyed or excavated, they have been subjected to cultural and natural processes, which Schiffer called c- and n-transforms (1987), conditioned by the length of time elapsed since their abandonment. Evidence from the Iraqi Jazirah shows sites more than 7,000 years old and less than 1m in height can be completely homogenized by soil-forming processes, leaving only the most resistant artefacts (Wilkinson and Tucker 1995), which in turn can be moved by further transformation processes, such as the actions of worms, ants or burrowing animals, making the actual site extremely hard to identify. These processes can transform items spatially, quantitatively, and relationally, causing spurious patterns and regularities, and affecting our ability to correctly identify sites, particularly when remote sensing methods are used (Altaweel 2005; Hritz 2013; Parcak 2007). Hritz, for example, notes how taphonomic processes, particularly those caused by the flow of the Euphrates,

> *"affect the visibility and composition of ancient features, making them difficult to identify and interpret. For example, the variation in soil composition of features, particularly anthrosols, has limited the utility of automated sites detection techniques … and unsupervised and supervised classification, in alluvial landscapes" (Hritz 2013: 1976)*

Nonetheless, if the site can be identified and visited, even in the most degraded deposits inferences are still possible, if the formation processes affecting them are understood. Schiffer (1983; 1987) listed key attributes which indicate formation processes: artefact size, density, frequency, orientation, damage / condition, use / reuse evidence and surface accretions. These can indicate fluvial processes of now-relict channels, soil movement, and site use.

The landscape as we see it today represents the cumulative effects of thousands of years of climatic and cultural events. Many processes, particularly cultural processes (c-transforms), result in selective loss or modification of the landscape. Although this study will primarily focus on c-transforms, many of which will be discussed in more detail shortly, numerous natural disturbance processes (n-transforms) can change archaeological contexts. However, Wilkinson (2003) noted that due to a wide range of factors which transform landscapes, there was only a general correlation between human and environmental variables and their effect on processes such as valley fills.

Darvill and Fulton commented (1998: 17) that the decay processes affecting sites are poorly understood – fourteen years later this still holds true, despite the large amount of work done on this subject, making damage hard to monitor. Processes are exclusive to the individual site, which will have undergone a unique life cycle of construction, use, re-use, desertion, dereliction, decomposition, deterioration and finally disappearance (after Darvill and Fulton 1998). It is dependent on the general nature of the site and its environs but the principal factors are: the durability of the components, the deposition environment, the post-deposition environment, the processes of attrition, and the effects of any subsequent human activities.

There are three types of environmental n-transforms (Schiffer 1987) which contribute to site decay. Chemical processes include acidic soil and atmospheric pollutants; biological processes include plant roots fungi and pests. Physical processes, however, have the most obvious effects. These include landslides and the effects of wind and water, which can alter site size or raise or lower land levels. Physical processes are particularly affected by site location. A site by a wadi, for example, is particularly likely to experience erosion. The aspect of the site and openness of location can affect the rate and area of aeolian deflation. Erosion rates, in particular, are also influenced by changing agricultural practices (Allen 1991), and soil particle size, and will be discussed in more detail in Sections 3.5.9 – Water Erosion, and 3.5.18 – Natural Erosion.

Certain soils on the lower parts of the Jazirah plain are continuously developing, "self-mulching" soils (Wilkinson and Tucker 1995: 5). In mounds that have not been reoccupied since a recognisable abandonment phase, the upper levels of occupation deposits have been transformed into a soil profile. These upper levels usually consist of mudbrick, mud floors, ash, or refuse: the uppermost 50-100cm of such deposits is then transformed into naturally appearing soil. On long abandoned sites (>2000 years old), the soil is moderately well developed. Charcoal and solid objects, such as pottery and large bones may be all that remain. As the soil continues to develop, all that may be left of the mudbrick is the 'ghost' of the walls – their colour remains, but the structure of the dense mudbrick becomes more akin to the soil, and the edges become indistinct. In the Jazirah, it is unusual to find archaeological layers in the upper 30-50cm of low mounds as a result of these soil processes. However, on high mounds, erosion means that the upper strata are constantly being exposed, so soil profiles never have the chance to develop.

A site approximately 1,000 years old will still retain mudbrick and artefacts in situ 40-60cm below the surface. Mudbrick from a site 1,700 years old will start to homogenise, but may still be visible, and archaeological deposits should remain perhaps 80cm deep. By 5,000 years, most of the upper levels will be gone: any remains will be at least 1 metre deep. Sites more than 7,000 years old and less than 1 metre in height may be entirely homogenized by soil formation processes, leaving only the most resistant artefacts (Wilkinson and Tucker 1995: 6, Figure 3). This has obvious implications for the impact of ploughing on a site, particularly on older sites where most of the evidence will remain as contextual information.

It is difficult to say at which points cultural processes have had a more significant impact on the landscape than environmental and climatic processes: the two are so interlinked it may not be possible to separate them. Today, for example, we see major economic investment in the landscape, but many areas of Syria are experiencing on-going drought. The lowering water table necessitates increased agricultural investment to achieve the same returns, in turn lowering the water table yet further. Nor are these impacts and their inter-relations static: they are part of an on-going fluctuating cycle. Nonetheless, it is only once these c- and n-transforms have been taken into account that the social, political and economic influences of humans on past landscapes can be considered.

3.3 –Landscape Survival – A Framework

The issues of site formation have moved beyond the level of the individual site: they inform the understanding of data used by archaeologists when interpreting landscapes at a fundamental level. Williamson (1998), for example, examined the processes affecting the English landscape, and questioned whether certain features or periods are apparently absent due to later land uses. Earthworks, for example, are often flattened by agriculture. Taylor (1972) first identified "landscapes of survival" and "landscapes of destruction" to describe areas of variable preservation. Although he applied them to the English landscape, and regardless of their conceptual simplicity, it is notable that a key characteristic of his zones of destruction is the same in Syria (despite the vast geographic separation) – intensively cultivated arable land. Features will remain in the landscape until a process strong enough to remove them occurs, but these processes are more likely in some areas than others.

Wilkinson took this concept, and adapted and developed it for the Near Eastern landscape.

> *"Landscapes with the greatest probability of feature survival occur in deserts and high mountains, whereas progressive loss of features is at its maximum in areas of long-term cultivation and rather less so in areas of marginal settlement … although it requires emphasis that the patterning of landscapes of destruction and survival can be extremely complicated"* (2003: 41).

Despite this complexity, they remain a useful conceptual framework. Wilkinson divided the landscape into five zones:

- Zone 1: Zone of Preservation in Deserts
- Zone 2: Zone of Preservation in Mountainous Areas
- Zone 3: Intermediate Zone (Marginal Rain-Fed Steppe, with Fluctuation Settlement Levels)
- Zone 4: Zone of Attrition
- Zone 5: The Coastal Zone

Case study 1, the Tell Beydar area (located in Chapter 2.1, Figure 2-12, described in Chapter 5), is an excellent example of an Intermediate Zone. The area is on the edge of marginal steppe, meeting the Khabur Basin where it becomes a Zone of Attrition. It is in this intermediate area - Zone 3 - that Wilkinson suggests "optimum landscape preservation" (2003: 42) may occur, as intense occupation in wetter (and therefore more reliably fertile) areas will have erased many earlier features, and the limited occupation in drier areas will have left few embedded traces. An entire relict landscape of the third millennium BC, complete with tells, hollow ways, and even some radial field systems, was still visible in this area on Corona imagery in the 1960s. Settlement there has fluctuated between dense occupation, such as that visible from the third millennium BC, and an almost complete abandonment by sedentary settlement (Chapter 5.4). Also within this area is the basalt Hemma Plateau which bears elements of Zone 2, a Zone of Preservation. The area has limited occupation evidence, and was probably used for grazing. A few Iron Age sites mark the only dated settlement on the plateau until the last century, and it is only relatively recently that it has come under cultivation again (if it ever was). This lack of more intensive occupation has left earlier more fragile archaeological features relatively well preserved: enclosures and rock art were recorded there as late as 2003 (Picalause 2004; van Berg et al. 2003).

Case study 2, the Land of Carchemish (located in Chapter 2.1, Figure 2-12, described in Chapter 7), is a complex area made up of terraces, limestone bluffs and fertile plains. The area of the river terraces (partially inundated, and partially destroyed by erosion) is a Zone of Attrition. The area was continuously occupied, and settlement was almost certainly concentrated here. However, this is difficult to confirm due to the rise of water levels resulting from the Tishrin Dam, although the idea is supported by evidence along the Sajur and elsewhere on the Euphrates. The limestone hills and the neighbouring areas are a decidedly marginal zone, with evidence of only intermittent occupation. As such it is expected that sites there would be relatively well preserved: however, the sites located in this area have often been damaged by the continued erosion of wadis draining the steep limestone terrain. The fertile upland plains have a long history of cultivation, and are another Zone of Attrition. This idea will be revisited throughout this study.

Whilst acknowledging that there is no such thing as a complete landscape record, this study aims to evaluate damage in these areas within this framework. Modern economic expansion has created a level of cultural destruction unparalleled in human history, and even marginal areas have now been reoccupied and intensively farmed. It may no longer be enough to peel back the palimpsest and recover past landscapes: interpretations must now first attempt to account for modern attrition.

3.4 – Factors Affecting Damage Interpretation

Not all threats have the same effect – some cause more damage to a site than others. Furthermore, sites are not equally significant. This should influence our conceptualisation of damage as a term.

3.4.1 – The Significance of Damage

There are several key factors which determine how significant damage to a site is (after Darvill et al. 1987: 396):

- **Rarity -** some classes of monuments are represented by very few surviving or known examples, others by a great many. The number of examples that once existed will never been known with certainty. Clearly the loss of one example of a rare class of monument is more significant than the loss of one example of a very numerous class of monument.
- **Period** – representivity: some classes of monument represent almost the sole source of information about their period, other classes will be just one of a wide range of monuments characterizing a given period... Monuments which are highly representative of a particular period are especially important.
- **Group value** – association: any monument has an enhanced value when it is associated with monuments of other classes. Two forms of association can be recognised: contemporary associations involving monuments of broadly the same date, and palimpsest associations involving monuments of earlier and / or later date ... the whole becomes greater than the sum of its parts.

- **Potential** - the nature of the evidence itself cannot always be specified precisely, but its' probable existence and importance has a bearing on the value of the monument as a whole.
- **Level of Documentation** – documentation relating to archaeological excavation, field survey / recording, historical records, etc.

These characteristics are important when assessing damage at the level of the individual site, although they will also affect any conclusions drawn on a regional level. However, in practical terms, assessing damage significance often requires more information than is easily available in a non-European context, such as detailed knowledge of the site gained through survey, aerial photography and sometimes excavation. Nonetheless, the Monuments at Risk Survey (Darvill et al. 1987; Darvill and Fulton 1998) remains perhaps the first work to conceptualise damage to sites in terms of significance and form a framework for analysing it. This will be discussed further in Chapter 4.2 – Background to Monitoring Site Damage (p117).

3.4.2 - Damage Extent

The extent of damage to a site is a key aspect of the significance of the damage. How much of the site is damaged? How large was the site to start with? Should our assessment of the threat be based on proportional loss, or relative severity? In the British Monuments at Risk Survey (MARS), Darvill and his team (1998) worked on the principle that decay is an on-going process, and that there are no absolute measures of survival, because the concept is relative.

> *"Even the statement that a monument has been totally destroyed is only a relative statement based on the assumption that something once existed but now does not. … Thus survival is a point-in-time measure of the current state or condition of a monument relative to some former state, a reflection of the cumulative effects of all the natural and man - induced processes that have operated on it"*
> (Darvill and Fulton 1998: 28).

They accepted that it was not possible to determine the original site extent, except in a few exceptionally well recorded or well-preserved cases. Efforts were instead made to document change over five decades, from the 1940s to the 1990s. The MARS team looked at site documentation, aerial photographs, and visited the sites to determine their Projected Archaeological Extent in the 1940s and Current Extent.

The case studies chosen here mostly only have one, or at most three, recent field visit records for each site, although some of the larger sites may have been visited by early archaeologists like Oppenheim or Mallowan. Determining early site extent exclusively from early satellite imagery can be extremely complicated, for reasons that will be discussed in the Methodology Chapter 4. Many factors affect site visibility, and there are no early field records to support interpretation. Furthermore, analysis of damage threats has shown that extent is an extremely simplistic indicator. As a result, this study instead splits damage into two aspects: horizontal extent and vertical extent. Whilst it is not possible to know the extent of vertical damage for sure from satellite imagery, and even in the field excavation may be required, certain threats cause certain effects, and these can be predicted.

3.5 - DAMAGE THREATS TO SITES

This section details the modern c-transforms or relevant n-transforms that are the causes of site attrition. As the aim is to assess their impact using satellite imagery, examples of how each threat appears will also be included, and some of the complexities. It must also be reiterated that, in some cases, the threat leads to the discovery of sites.

3.5.1 – DEVELOPMENT

Development in this context refers to the expansion of buildings across the landscape, from the enlargement of towns and villages and the building of small single structures. Most buildings in the case study areas were assumed to have a residential or agricultural purpose (depending on size, concentration or location), although some buildings were known to be military, such as the outpost on the top of Carchemish. It is probable that some buildings which were assumed to be agricultural were in fact industrial, but as they were probably intended to process agricultural products, the distinction is not relevant in this study. Development is easily detectable on imagery, even on early, lower resolution images, for example Figure 3-2 shows Tell Beydar and its associated village on 1967 Corona. Development causes significant problems to sites: modern settlements are often located on or around old sites (as seen in Figure 3-3 and Figure 3-4), and they are both increasing in number, and rapidly expanding. As few examples of pre- and during-development monitoring occur in the Middle East, many of the following examples are drawn from European or western contexts.

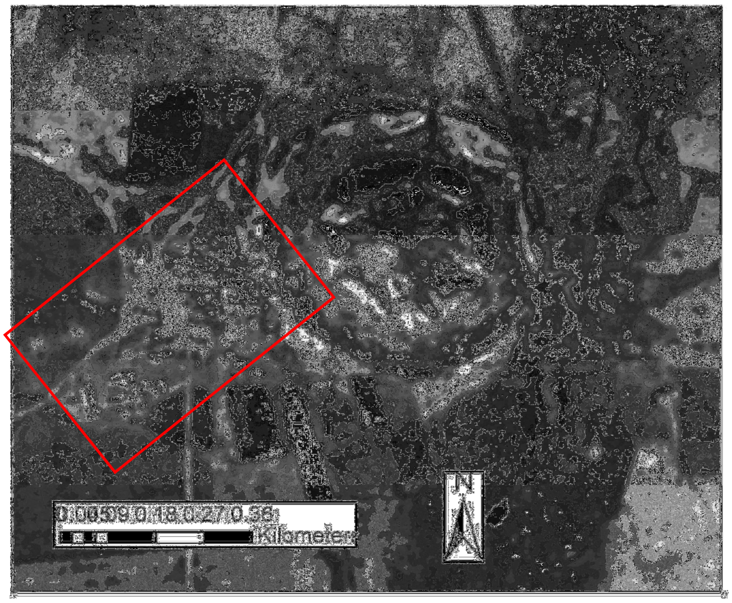

FIGURE 3-2: DEVELOPMENT TO THE WEST OF TELL BEYDAR (TBS 1)[12]

"Experience suggests that, where development is not intensive, some deposits may remain undisturbed, but as a rule destruction is total" (Darvill and Fulton 1998: 132).

The MARS survey observed that 36% of archaeological monument destruction was caused by road building and construction: demolition and building works were responsible for a further 20%. This, combined with the introduction of the 1992 Valetta Convention, which required *in situ* preservation of archaeological remains wherever possible, led to the first European studies in damage to archaeological sites caused by development. It is accepted that this may not be entirely applicable to a Middle Eastern context: however, even recently it was acknowledged that far more research was needed in this field (Huisman 2012). Although some further European studies are underway, no other information is available. Where possible therefore, the available information will be extrapolated to Middle Eastern sites.

Making it even harder to assess the effect of damage on sites, changing conditions over time must be allowed for, including ground and soil conditions, development types, development lifespans, economic building constraints and technical concerns (Nixon 1998). Although many effects can be mitigated at the design stage, or by using particular equipment, mitigation measures are usually included as part of a statutory requirement to protect archaeology *in situ*, which is not part of the Syrian legal

[12] Corona image, 1102-1025df006-1, standard deviation stretch, 09 December 1967

framework, and thus is rarely taken into account. In the case study areas small buildings with shallow foundations are the most common development type, although some buildings involve more extensive construction.

The Construction Process

The construction process occurs in stages, each of which has specific effects (Davis et al. 2004).

A pre-construction ground investigation is usually conducted, particularly for larger developments, potentially involving ground-intrusive engineering operations which may damage buried archaeological remains. For example, on a large site, fencing necessitating shallow foundations may be required. Vegetation removal and topsoil stripping can cause extensive physical disturbance, as it exposes the subsoil to compaction and contamination from machine traffic, as well as the influence of weather fluctuations (e.g. freeze /thaw cycles and waterlogging). Test probing, demolition, site clearance and shoring all occur during pre-construction, as well as ground improvements such as dewatering of high water tables, or soil testing. Weak soils may be strengthened with cement or other chemical grouts, or removed and replaced, potentially encasing archaeological remains.

However, the main impact on archaeological remains usually results from the actual construction, beginning with ground preparation. This usually commences with topsoil stripping, followed by the extensive removal or strengthening of weak ground. The construction of foundations and installation of buried services causes the greatest impact. Heavy machinery is required for this work, and even if otherwise unaffected, near-surface soils are likely to suffer some degree of disturbance which may impact archaeological remains.

Even once development is completed, post-construction remedial and maintenance activities can cause further damage. Buildings may need repair, potentially causing ground disturbance and services may need cleaning or renewing, traditionally using trench excavation.

In general, the construction and development activities which disturb archaeological sites can be split into 5 key damage types (Huisman 2012), although the amount of information available on each cause varies.

1) Disturbance caused by digging

2) Disturbance caused by piling
3) Compression
4) Degradation through change in the burial environment (including hydrological, geochemical and biological changes)
5) Non-physical effects, including inaccessibility for monitoring and research, during and after the lifetime of the construction. Although it is clearly an issue, it is not the purpose of this thesis to quantify this effect, and so it will not be discussed further.

Disturbance Caused by Digging

The effects of digging include soil mixing, displacement of soil material and loss of context for artefacts. In principle, they are easily predicted, as they should follow a building plan but in many cases plans are not detailed enough, are changed, or did not include service infrastructure.

Even the pre-construction assessment can cause considerable damage. For example, on a small urban site of uniform geology upon which a simple medium rise structure is to be erected a borehole is required on each corner of the site and others spaced every 40-50m or so across the site. Trial pits are also dug approximately 25m apart and are up to 4.5m deep, 4 m long and just under a metre wide. Complicated structures require more boreholes and trenches (c 20m apart) (Davis et al. 2004).

Fencing foundations for large construction sites require excavations every 1.5 – 2m around the site to a depth of 750mm and a diameter of approximately 300mm. Similar fencing may be required for certain features or structures. During topsoil stripping and ground preparation, soil is commonly removed to depths of 5m in the UK, but can occasionally be removed up to depths of 20m or more. Access roads, contractor accommodation and site storage facilities may be constructed, some requiring more extensive ground disturbance, as well the potential removal of soft areas of ground and the laying of a firm granular base (Davis et al. 2004).

Shallow foundations are usually less than 2 metres deep, but can go as deep as 5m. They yield greater settlement and lower load carrying capacity, as well as costing less than deeper foundations. They tend to be used on lower cost projects, where foundation loads are low in comparison to the bearing capacity of the soil. There are several different kinds of shallow foundations, which cause different amounts of ground disturbance.

Deep foundations can exceed 5m, and are used if the foundation loads are high in relation to the allowable bearing capacity of the soil, settlement criteria are stringent or construction factors such as a high water table make shallow foundations less economic. Deep foundations act to shed superstructure loads into strong deposits at depth below the ground surface. This is usually achieved by constructing piles. Service lines are also usually marked out during foundation construction. Trenches may be necessary to lay drains, pipes, cables, access chambers and to connect the services into pre-existing systems (Davis et al. 2004).

If the building contains a basement, there can be a substantial removal of soil and then the foundations are constructed underneath. However, many smaller or poorer buildings do not have basements, minimising the damage.

Disturbance Caused by Piling

"Piling is a method of transferring load from a structure into the ground" (Williams et al. 2007: 3). It is undertaken as part of the construction of foundations to spread the load of the building. There are many types of piles: the choice depends on the proposed structure type and location, ground conditions (including location of water table), durability of materials and cost (including speed of installation). The two main types are displacement piles, which are driven into the soil, radially displacing soil and damaging deposits, and non-displacement piles, where soil is excavated first and the pile installed in the cavity (Davis et al. 2004). (For more information on pile types and effects see Davis et al. 2004 (Appendix A); Huisman 2012; Huisman et al. 2011; Williams et al. 2007).

Sizes vary from 150mm to 2m in diameter, and may be more than 100m deep, although 10-30m is more common in the UK (Davis et al. 2004). They can cause so much damage it may not be worth excavating the site later, even if they were designed to preserve as much of the site as possible. Different piles will have different impacts on the archaeological resource depending on the type, the installation method, the soil type and the type of the archaeological resource. There is, as yet, no comprehensive list of effects which takes all these variables into account but in general

> *"All techniques result in damage or loss of artefacts, and in sediment deformation equal to at least the total volume of the pile of vibro-replaced column. This is the minimum impact that will result from any piling operation. In many cases further disturbance may occur …. Additionally, hydrological impacts on the deposit may affect the*

> *deposit/groundwater chemistry and microbiology"* (Williams et al. 2007: 8).

Displacement around driven piles can be equal to or larger than the diameter of the pile. Most evidence is qualitative: damage was recorded when it was observed, but effects of soil type and so on could not be accounted for to generalise the effects elsewhere. Around one pile, displacement of archaeological soil was recorded in an area quadruple the diameter of the pile driven into the soil (Nixon 1998), whilst at other sites no displacement was recorded (Williams et al. 2007). One of the only scientific studies was conducted by Huisman et al. (2012; 2011), which examined the impact of a specific pile type up to a certain depth in different soil types. They concluded that in fine grained soils, the extent of disturbance of soil around the pile is virtually identical to pile volume, but that if sand layers were present in the soil, the effect was greater, although the impact of depth on disturbance was unknown. Further studies are now underway to investigate other variables.

Replacement piles can cause even more damage, as they are made by augering, which can drag the surrounding soil, damaging any archaeological remains, particularly if the soil contains any large remains or stones (Huisman 2012).

Further associated potential effects caused by piling include pyrite formation in peat layers, damage to friable materials and locally increased pressure, although this was only observed once (Huisman et al. 2011). Drilling fluids, grout and wet concrete can leach into the soil, damaging remains, and piling has also been linked to changes in the hydrology of the site, draining waterlogged deposits (Williams et al. 2007).

<u>Disturbance Caused by Compression</u>

Development can cause the compression and deformation of layers: construction of foundations, for example, creates a load that did not previously exist, potentially causing soil compaction, or lateral spreading. If this occurs quickly, and artefacts do not have time to adjust, breakage, rather than deformation, may occur. Under pressure, shearing can occur (physically moving the soil and archaeological remains), resulting in damage to the stratigraphy or context, as well as direct damage to materials (including artefacts). Lack of information on the impact of compression and loading on archaeological sites is a major problem (Davis et al. 2004; Huisman 2012).

Degradation Through Change in the Burial Environment

Changes to the soil structure, alterations to the water-regime and addition of foreign materials can all cause changes in the burial environment. Water-regime changes include alterations to retention, exclusion, changes to flow patterns and rates, quality and temperature, all of which can affect soils and materials. Effects can be physical (e.g. abrasion), chemical (e.g. the creation of electrolytes) and / or biological (e.g. aerobic / anaerobic processes) (Davis et al. 2004).

The most common problem is the (often temporary) lowering of groundwater tables, causing desiccation. Since knowledge on the speed of decay is lacking, it is hard to predict damage. It is assumed organic remains degrade quickly, whereas processes like metal corrosion and acidification are slower and may be less affected by temporary changes in water ground level. If the ground becomes increasingly wet and oxygen decreases, soils may change colour, making archaeological features extremely difficult to distinguish from the surrounding soil. This is more likely to occur if the sediments are fine-grained, if the reduction-oxidation boundary is close to the archaeological levels and / or if the soil shows evidence of changing redox (reduction-oxidation) conditions, also known as gley features (Huisman 2012).

During the creation of some pile types, wet concrete is installed into the excavated cavities. This can cause problems as, even if it does not leach, wet concrete is highly alkaline and can cause raised pH and raised cation concentration, increasing the decay rate of some materials. Leached fluids, such as drilling fluids, can also cause chemical or biological changes to the soil. There is also some evidence that foundations can act as pathways for the movement of salts through a site, allowing efflorescence to occur (Davis et al. 2004).

Site Types and Development Impacts

Many sites in this area are dense tell sites, of which only part will be damaged by development. In general, modern rural villages cut into the upper levels of sites for foundations and infrastructure. As discussed in Section 3.2 - Landscape Formation and Transformation Processes, and 3.5.18 – Natural Erosion, not all of the uppermost parts of the tell are necessarily of archaeological value. On shallow tells, or those with relatively flat summits, such as Tell Effendi (TBS 55, Figure 3-62), the upper levels are composed of mudbrick and ash which has degraded back into soil, forming a layer which partly protects the archaeological layers. However, the depth of this level varies unpredictably between sites. On steeper tells, constant natural erosion processes may keep pace with soil formation, revealing and eroding the top of the tell, and slowly lowering it. In some cases, buildings also cut into the sides of a tell, penetrating straight past the 'protective' layer, deep into the archaeological layer. The increase in buildings is also associated with an increase in roads and other related threats.

FIGURE 3-3: TELL YOUSEF BEK (LCP 59) SURROUNDED BY A RECENT VILLAGE, JULY 2010[13]

FIGURE 3-4: BUILDINGS ON AND AROUND TELL KOULLIYE (LCP 50) ON SATELLITE IMAGERY[14]

[13] Photo copyright: the author

[14] DigitalGlobe image, 27 May 2003. Taken from Google Earth 06 October 2012

If the site is flat, or has standing remains, rather than a dense tell, the damage can be catastrophic, destroying the site without trace. Kennedy and Bewley's aerial survey around the rapidly expanding Greater Amman in Jordan noted the apparent near-total destruction of

> "*small towns, villages, farmsteads, mansions, rural churches and shrines, burial places, industrial sites and the network of roads linking them. Due to modern development, such remains ... have largely disappeared... In most cases they were recorded only superficially; sometimes not at all*" (2010: 198).

Studies in Syria have demonstrated the same level of threat. Figure 3-5 shows the plan of House C, in the outer town at Carchemish, surveyed by (Woolley 1921). The Land of Carchemish Project surveyed the remains of the outer town amongst the modern town of Jerablus in the 2010 field season (Wilkinson et al. 2011). Figure 3-6 shows the remains (or lack) of House C, which is now partly destroyed by a new building, which was not present on the 2009 imagery. As can be seen from the sequential imagery, the area was a partly empty lot in 2003; an orchard was present in 2008, and by 2009, building had started (Figure 3-7to Figure 3-9).

As a damage category, development reflects both urban expansion (either of new or existing settlements), and the increase in small properties, such as pump houses, farmhouses, and storage facilities. Even small single developments, such as the building visible on Tell Jamilo (Figure 3-1) can cause damage through the development of the supporting infrastructure, such as digging to lay electricity cables. When recording the damage causes, no distinction is made between urban settlements and small single structures, as this is defined under the extent of damage caused, although this was recorded in the land uses around and on sites. As it is not possible to know the depth of the site without excavation, or the depth of the development, unless further information is available, development is assumed to only damage the upper levels of a site (although see the Carchemish Development Section 8.7.1 for an applied discussion of these issues, p357).

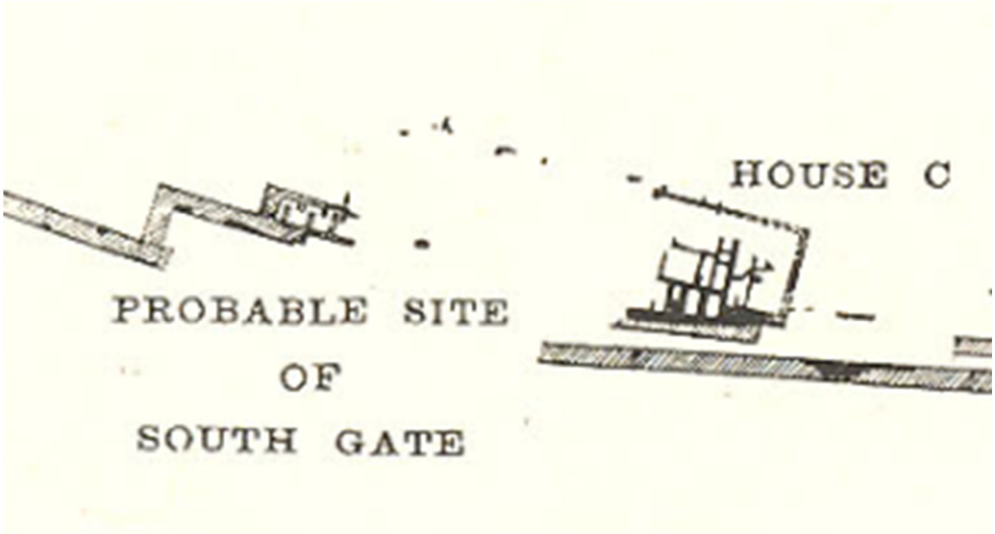

FIGURE 3-5: PLAN OF HOUSE C IN THE OUTER TOWN OF CARCHEMISH (WOOLLEY 1921)

FIGURE 3-6: REMAINS OF HOUSE C IN JERABLUS IN JULY 2010[15]

[15] Photo courtesy of the LCP Group

FIGURE 3-7: SITE OF HOUSE C, 2003

FIGURE 3-8: SITE OF HOUSE C, 2008

FIGURE 3-9: SITE OF HOUSE C, 2009[16]

Note how part of the empty plot (in 2003) where House C is located has an orchard planted on it by 2008, and a new house in the space in 2009.

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[16] Top: DigitalGlobe Image, 02 September 2003. Middle: DigitalGlobe Image, 01 June 2008. Bottom: Geoeye Image, 26 July 2009. All taken from Google Earth 08 October 2012

3.5.2 – *Agriculture (Arable and Grazing)*

Agricultural damage comes in several forms. The most common is the ploughing, planting and harvesting of cereals. Animal grazing also causes limited damage, as does the planting of orchards. Both arable agriculture and orchards cause more damage than animal trampling, although the effects vary according to the methods used for planting and harvesting and are dependent on the site type. These will be discussed in more detail here and in the next Section 3.5.3 – Orchards).

Perhaps more than any other type of threat, agriculture holds a unique place in damage analysis, as it frequently acts to protect sites from worse damage. At the lower town of Carchemish, for example, the orchards have acted as a buffer against further expansion of the modern town of Jerablus, damaging the site, but protecting it from worse destruction (Wilkinson and Wilkinson 2010). In the recent conflict in Libya, shepherds were allowed to graze their animals on the World Heritage Site of Leptis Magna in exchange for guarding the site: that way intruders were detected and no further protection measures needed to be taken (Kila 2012).

According to (Kirkby and Kirkby 1976), after a century, 37% of original surface sherds from a buried site will still be on the surface, but after a thousand years only 0.004% will be, decreasing the chances of detection. Agriculture, particularly ploughing, has the beneficial effect of bringing finds to the surface, enabling their discovery, but continued ploughing will disperse the sediments, sometimes until the site is gone. The Sussex Plough Damage survey, conducted for the British Department of the Environment estimated that 38% of 1,200 surveyed sites were actively destroyed by ploughing (Drewett 1980).

Arable Farming

Today both the Tell Beydar area and the Land of Carchemish are almost entirely agricultural areas (excepting the necessary villages, tracks and roads). As discussed in Chapter 2.3.3, much of the intensification is a post-war development, significantly impacting on the landscape. The indicators of arable agriculture can be hard to determine on lower resolution satellite imagery. It is not always possible to differentiate between low scrub and crops on Corona and SPOT, as field boundaries are not necessarily obvious in certain seasons or on certain land types, particularly on the limestone hills of the area around Carchemish. Ploughing is easier to distinguish on Corona, as the characteristic envelope patterns of ploughing are sometimes visible (as shown on Figure 3-10), but it was variable, and so not recorded consistently, and it is almost never recorded on SPOT imagery.

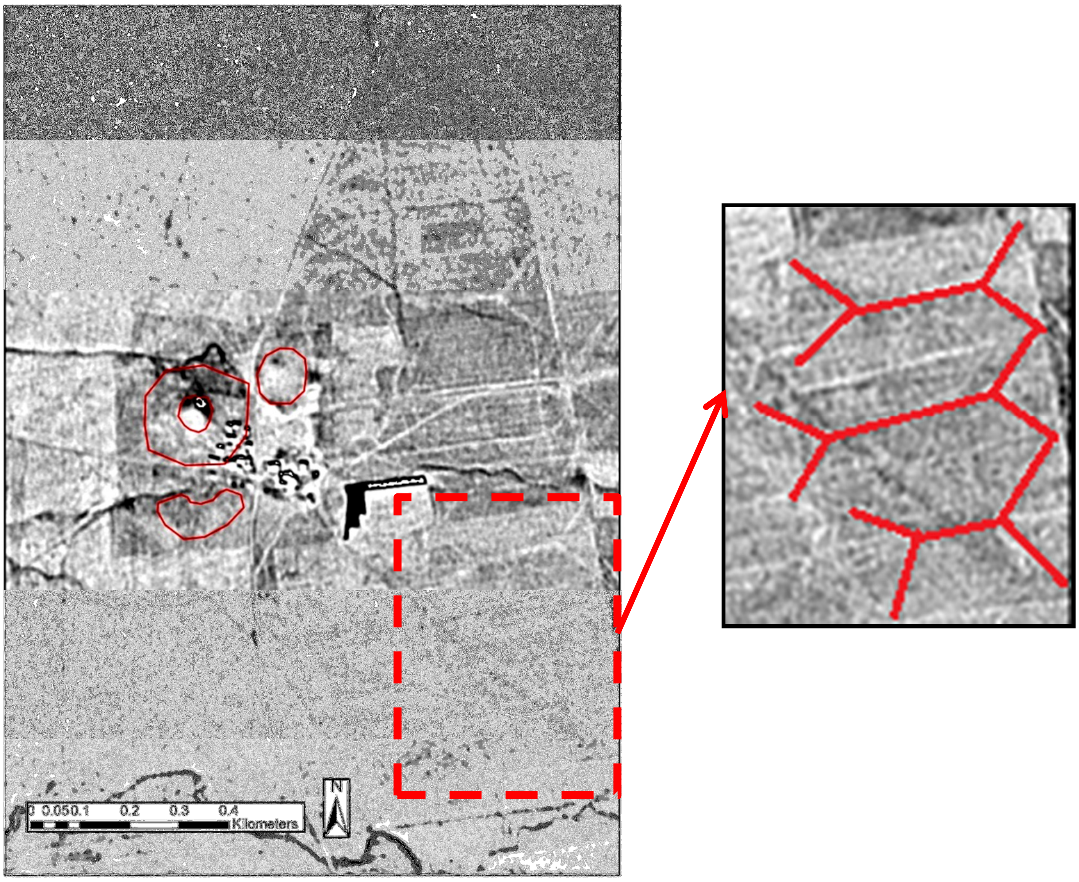

FIGURE 3-10: ENVELOPE PLOUGHING EAST OF TBS 63[17]

It is only on the later, higher resolution imagery, plough lines become easy to see. Today, as will be shown, most sites are in regularly ploughed fields under agriculture. Low mounded sites and flat sites are almost all under arable cultivation or orchards, and even higher sites are farmed if it can be done. Tell Farfara (TBS 52) is 13m high, and yet satellite imagery shows plough marks on the slopes (Figure 3-11 below). This issue is discussed in more detail in Chapter 9, where the relationship between damage and height is analysed.

[17] Corona Image, 1105-1025df057-6_37N, standard deviation stretch, 03 November 1968

FIGURE 3-11: PLOUGHING ON TELL FARFARA (TBS 52), A 13M HIGH SITE[18]

Sites in a zone of preservation are relatively undisturbed, their sediments and finds still largely representative of where they were formed or deposited. The effects of tillage and the damage it causes, particularly in marginal zones which are being reclaimed, are frequently underestimated by archaeologists. Ur is one of the few authors to comment on this damage, noting the effects of agriculture in the area around Hamoukar, further east on the Jazirah:

> *"Most sites have probably been reduced in height, since agriculture has removed the steppe vegetation that anchors the soil; sites are now much more susceptible to aeolian deflation and erosion via surface run-off. … Whether via plow or erosion, therefore, the surface assemblages of many sites have been diffused to some extent across the landscape … The stripping of natural vegetation and constant tilling of the landscape, and the movement of sediments that results from these activities, have obscured many landscape features with subtle topographic expressions … The churning of the upper soil horizons has, however, maintained the visibility of field scatters by keeping them close to the surface"* (Ur 2010b: 43).

Ur also noted that modern ploughing is breaking sherds into smaller pieces, which, together with the increased dust from the lack of anchoring vegetation, will affect their visibility. Given that in many landscape surveys, both the discovery of sites and their dating is dependent on sherd visibility, this will have obvious consequences for site discovery and sequential settlement patterning.

[18] Geoeye Image, 23 June 2010. Taken from Google Earth 08 October 2012

In fact, the effects are multiple and can have serious consequences, particularly for survey archaeology, which is often dependent on field walking and pottery collection.

> *"Any attempt to interpret the archaeological significance of material collected by field walking is primarily dependent upon one assumption. Namely that surface artefact scatters can be interpreted as products of past human behaviour despite the fact that they have been subjected to a particularly severe form of post-depositional disturbance"* (Taylor 2000: 16).

Therefore anything which affects the patterning, composition or density of the archaeological assemblage can alter our perception of sites, and the identification of locations of human activity in the landscape.

(Hinchliffe 1980) specified several broad categories of threat for sites in the UK.

1. The disturbance of previously unploughed sites by being taken into cultivation. A large amount of damage can be done in a short space of time.
2. Whilst ploughing may remain at a continuous depth, this will result in the gradual incorporation of levels of archaeological interest into the plough soil.
3. Increasing the depth of disturbance on a site that has already been under cultivation for some time, on which a measure of stability may have previously been achieved.
4. The continued erosion of a site from soil loss, potentially caused by the baring of soil from cultivation. Erosion may redistribute archaeological material.

The initial (and perhaps most extensive) damage occurs when the site is brought under cultivation. Mouldboard ploughs, for example, operate between 25–40cm, although some surpass 50cm. Modern tractor-drawn mouldboard ploughs are the primary cultivation tool of most farmers, and are more likely to bring material to the surface from depth as they invert the soil when they cut into it. They are semi-mounted on tractors and the depth varies according to the depth of the plough soil, in order to avoid ploughing into the bedrock and damaging the plough. Cereal crops tend to be ploughed to a depth of 12.5-20cm, although this is dependent on the soil type. Ploughing rarely exceeds 30cm, and archaeological remains in the subsoil are usually unaffected (summarised from Bonney 1980; de Alba et al. 2006; Lambrick 1980; Nicholson 1980; Taylor 2000).

Once the topsoil is prepared, sites undergo regular ploughing. In Syria cultivation commences in November when the first rains are expected and winter crops are sown.

Crop rotation is practiced, and generally speaking, a two year rotation on the hills, and a three year rotation on the plains has given way to annual cultivation in recent years. As fallow land is no longer communal grazing territory, summer crops such as legumes are often now grown. This intensification has also allowed expansion onto land which had only rarely been previously farmed. In some areas, the land is owned by distant landlords, who do not invest in the land and do not let it lie fallow, as they are not concerned with its long term fertility, but only with short-term gain (Palmer 1999).

Several archaeologists conducted experimental archaeology and studied sites to examine the effects of ploughing on archaeological sites (Ammerman 1985; Ammerman and Feldman 1978; Boismier 1997; Clark and Schofield 1991; Crowther 1983; Crowther and Pryor 1985; Diez-Martin 2010; Frink 1984; Lewarch and O'Brien 1981a; b; Odell and Cowan 1987; Reynolds 1982; 1988; Reynolds and Schadla-Hall 1980; Shott 1995; Trubowitz 1978; Yorston 1990; Yorston et al. 1990). The following discussion represents a brief synthesis of their work.

Once a site has been ploughed, studies showed that surface samples represented between 0.3 – 16.6% of the total artefact assemblage buried at the site. Most experiments took place over less than a decade: average sherd movement was less than 4m, but some moved up to 18m in that time. Roper (1976) carried out a long term study: after 2-3 decades of ploughing, artefacts were displaced anything from 20cm to 10m. On sloping sites, heavier artefacts moved downslope, followed eventually by soil and lighter artefacts, particularly if ploughing is along the gradient, rather than horizontal.

Different structures undergo different effects when ploughed. Buried structures can be slowly destroyed level by level until what remains is not worth excavating. In the early stages of ploughing, there will be remains of the structure itself – some walls, the floor, occupation levels. Once these are gone there will be structural evidence only, such as foundations and post holes. Finally, only the deepest features will remain – pits and ditches. Earthworks on the other hand experience erosion and the alteration of their visible form. The form is significant to the typology of the site, and can act as a protective layer over earlier remains, perhaps sealing a horizon of contemporary soil, which can provide a context for the conditions at the time the monument was built. High tells with multiple layers of mudbrick remains are less susceptible to plough damage, but the smaller dispersed sites with little depth, such as those seen in the Iron

Age and Roman period around Carchemish (Peltenburg 2006; 2007b; Wilkinson and Peltenburg 2010; Wilkinson et al. 2007) can be badly affected as they have little depth.

In theory, if a site is ploughed, and artefacts undergo a gradual dispersal, eventually there will be nothing left of the site. Some archaeologists argued that sites reach equilibrium, a point at which the average movement effectively becomes zero, and whatever remains of the site stabilises. Whilst individual sherds may be moved by the plough, the site does not disperse any further. Suggested figures for this to take place were after 9-12 ploughings. Critics argued that there is no evidence for any sort of equilibrium, and that in fact the evidence suggests artefacts will continue to disperse. However, plough soil sites clearly do persist: the assemblage does not all end up at the edges of the field, so some sort of equilibrium must be reached. Indeed, despite decades of intensive ploughing, many sites in the near east are still visible on satellite imagery, and have been detected in recent field visits.

Redman and Watson (1970) studied two prehistoric mounds in Turkey, dating to 7,000BC and 5,000BC respectively, to examine the effect of long term ploughing. Both sites were cultivated with draft animals for an unknown but probably long period of time, with furrows 10-12cm deep. Approximately 3000 ploughings were suspected. They surveyed the area intensively prior to excavation: the artefact distribution did not follow field boundaries – finds were in fact split by modern field boundaries, suggesting ploughing had not substantially affected the distribution. However, the areas with the highest surface yield in the topsoil had the fewest remains and intact features. Bowden et al. (1991) found similar results at Weathercock Hill on the Berkshire Downs.

Only one study examined the effects of modern, intensive ploughing over time. Hurtado (2000) studied the Copper Age settlement of La Pijotilla in Spain. Agricultural work in the 1980s brought to light a concentration of archaeological remains. One concentration was microspatially recorded. There was a direct relationship between the surface finds and the tomb underneath. However, two further tombs were recovered with no evidence on the surface to suggest they were there. The introduction of modern agricultural machinery had greatly affected the upper archaeological levels, and the effects of the machinery were not uniform across the site. Evidence from cores suggested remains had moved at least half a metre. Hurtado also noted that in the 1970s circles of ash coloured soil (later shown to be vegetal material) had been visible to suggest habitation areas. By the mid-1980s, only artefact concentrations like pottery and lithics remained.

Clearly then, agriculture has an effect on the site, particularly on shallow sites, but it is dependent on site type and material, soil type, gradient, and type, extent and length of ploughing. On more dense sites, such as tells, the key damage comes from erosional processes. As demonstrated in the Tell Beydar analysis of agricultural damage (Chapter 6.7.2, p248), field sizes have increased, field boundaries are fewer, hedge rows have been removed, and double cropping has been introduced, meaning soil is exposed to the weather more often, all of which affect erosion rates (Allen 1991). Ploughing continues to remove vegetation which would otherwise hold the topsoil together. Figure 3-12 shows ploughing on top of Tell Dadate (LCP 25), which is 9m high - only the shallower slope was ploughed, although even this was relatively steep. Cultivation also usually reduces the levels of organic matter in soils, usually to less than 4%. Below this level it becomes hard to maintain soil structure (Morgan 2005). The effects of erosion are discussed in Section 3.5.18 – Natural Erosion.

FIGURE 3-12: PLOUGHING ON TELL DADATE (LCP 25), JULY 2010[19]

Agriculture also affects the landscape, and in this way can be used as a proxy for the intensity of the effect on sites. In particular the wadi channels which once provided water for settlements are now dry and ploughed out. At TBS 56, for example, the site notes record "To E a shallow wadi is without a channel and is completely ploughed

[19] Photo copyright: the author

over". Similar landscape change was recorded in the Iraqi Jazirah, more than a decade earlier – "By the time of the first season (1986-1987) a large number of wadi channels were already completely ploughed across" (Ball et al. 1989: 9). This feature removal indicates the intensity of ploughing and the speed with which change is occurring, as shown in Figure 3-13, which shows the ploughing out of a wadi at TBS 5. It is assumed here that the ploughing effort required to smooth over land once incised by a wadi could also cause serious damage to any nearby sites.

Increasing agriculture causes further problems. Fields in irrigated areas often have two or even three crops a year, decreasing the amount of time bare soil is visible, and thus the "window of opportunity to collect appropriate imagery that contains predominantly bare soil to prospect for soil marks" (Beck 2004: 145). Conversely, the amount of time in which crop marks may form increases. As will be seen in the analyses of damage in the case study areas, it is often dependent on the individual site whether it is more easily visible on bare soil or as a crop mark.

FIGURE 3-13: RELICT WADI CHANNEL BY TBS 5 ON GEOEYE[20]

The red arrow on Figure 3-13 indicates a remaining isolated fragment of the old wadi channel, before the Wadi 'Awaidj was diverted into the concrete channel (blue arrow). The black arrow indicates where this channel has been ploughed out, i.e. it is no longer present.

[20] Geoeye Image, 17 August 2010. Taken from Google Earth 21 January 2012.

Grazing Animals

The second form of agricultural damage is caused by grazing animals. In particular, whilst grazing can improve visibility, animal trampling causes artefact breakage, differential artefact visibility and displacement, which affect lithic analyses of function (Blasco et al. 2008; Eren et al. 2010; Osborn et al. 1987; Ur 2010b). Whilst they will have little effect on tells, animals can also be quite damaging to stone-built structures, where there is an enhanced possibility of erosion and the collapse of stonework. However, grazing can be indirectly beneficial, as grazing gives the land an additional value, and so it may be less likely to be brought into another type of use. However, this should not be relied upon: in the 1960s, the unprecedented intensity of expanding cultivation also led to the loss of forage plants traditionally grazed by the Bedouin: the government had to provide almost all forage plants (Nyrop 1971).

Grazing is virtually impossible to determine from satellite imagery unless the animals are present in the field when very high resolution images are taken (such as Figure 3-14), and so there is no comparative analysis in this study, but when visible it is noted.

FIGURE 3-14: GRAZING AT APAMEA, JULY 2010[21]

FIGURE 3-15: ANIMALS GRAZING IN FIELDS IN THE LCP SURVEY AREA[22]

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[21] Photo copyright: the author

[22] Geoeye Image, 26 July 2009. Taken from Google Earth 10 October 2012.

3.5.3 – Orchards

Orchard groves for olives and pistachios are becoming increasingly common in Syria, causing substantial damage (Figure 3-16), and new areas are being prepared for them all the time. The importance of olives in Syria dates back at least as far as the late Roman period. They were an important cash crop then (Ball 2000), although by 1999 the modern Syrian government were offering schemes to support cash-crops like cotton – the new olives! Olives have unpredictable yields - a good crop tends to be biennial - and they are slow to establish. Yet many farmers are still converting their land to orchards, partly as they are considered easier to grow (Palmer 1999) as they are less labour intensive than many field crops. In 2010 Syria was a major exporter of olives and intended to continue to increase production.

Figure 3-16: Orchards in the World Heritage Site of Serjilla, July 2010[23]

It is unclear in what ways the earth is prepared for them first, but the holes for each tree in the plantations are approximately a metre deep. In some parts of Homs, the soil can be as shallow as 30cm, so holes for tree planting are deep enough to churn up bedrock, obliterating the site. In other areas, the disturbance of the sub-surface soil increases overall reflectance, and makes site easer to see (Prof. Graham Philip, *pers.*

[23] Photo copyright: the author

comm. 2011). Very few sites are more than a metre below the ground, although such depths are known in some river valley bottoms, or near the base of hills. Orchards therefore disturb the upper levels of deeper sites when they are planted, and can cause deeper damage depending on the planting method used and the depth of the site. As satellite imagery does not reveal the depth of planting, a best case scenario is assumed where only the upper levels are damaged. However, once the trees are well established, the root network spreads and develops and can cause extensive damage.

Like other forms of agriculture, orchards can also act to protect sites from further, more extreme, damage. At Carchemish, for example, the orchards (visible on Geoeye) are damaging a substantial section of the lower town, but, equally, they are preventing the encroachment of the modern town of Jerablus, which would be much more destructive. Figure 3-17 shows Woolley's map of the lower town over a 2009 Geoeye image. The speckled area shows the orchard, and the town is at the bottom. Orchards are very difficult to see on early imagery; few were visible in the survey areas, but even small orchards are clear on later imagery (such as in Figure 3-8, p56).

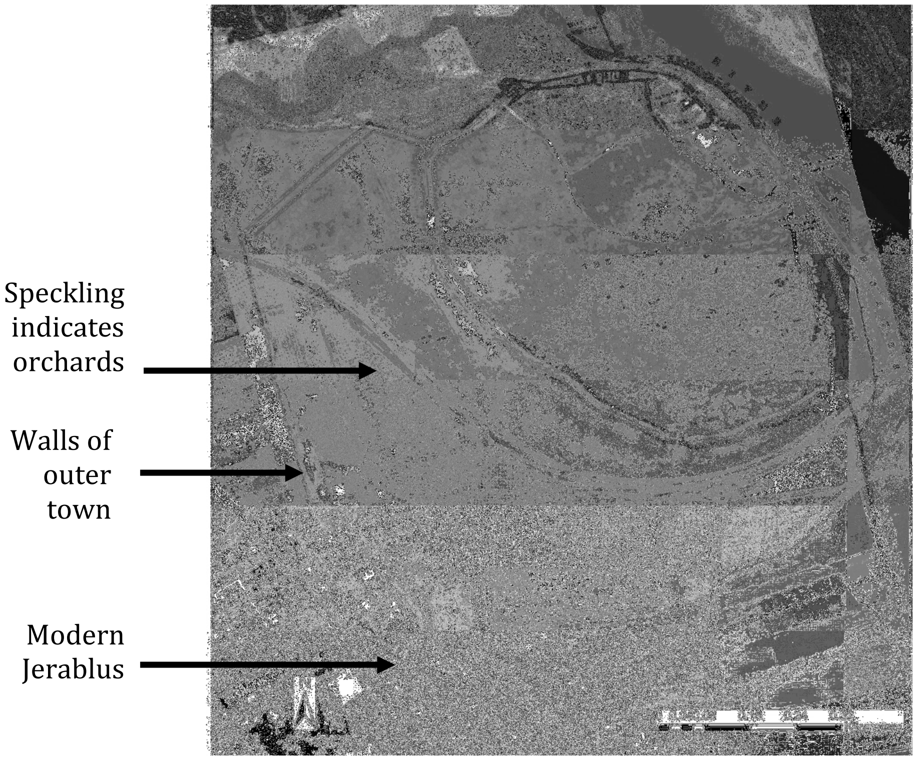

FIGURE 3-17: VISIBLE ORCHARDS ON THE OUTER TOWN AT CARCHEMISH[24]

[24] Geoeye Image November 2009. Map: Woolley, C. L. 1921. *Carchemish. Report on the Excavations at Jerablus on Behalf of the British Museum. Part Ii: The Town Defences.* London: The British Museum.

3.5.4 – Irrigation

Irrigation is becoming a major threat, even in areas which are not considered to be heavily irrigated. This is presumably linked to the decrease in available water (discussed in Chapter 2.3.3): irrigation has become necessary to support the intensive agriculture required for commercial cash-crops crops, and in order for crops to return the same yields despite the drought and dropping water table. Irrigation enables the cultivation of multiple crops yields each year, which has the positive effect of decreasing the amount of time the soil is bare (Beck 2004: 145), but which in turn decreases the window the site is open to erosion. As well as the direct damage caused by cutting channels through the site, irrigation can significantly impact site visibility, particularly if the water is from lake or riverine sources rather than ground water. The sediments contained within the water are redeposited on the surface of the fields: as detected reflectance is a feature of the surface soil layers, this new sediment will play an increasingly large role in reflectance and may begin to mask the presence of the underlying archaeological deposit (Prof. Graham Philip, *pers. comm*. 2013).

In the Land of Carchemish area, irrigation is more likely to take the form of groundwater wells and riverine pumps (Figure 3-18), which are harder to see on imagery. Around Beydar, long irrigation channels are visible extending across the fields from groundwater wells, and in some cases, extending from the West Hasseke Dam. This section also covers the damage done by the dam reservoir bed, which is a major source of irrigation water.

Figure 3-18: Irrigation Pump on the River Sajur, July 2010[25]

[25] Photo copyright: the author

Channel Irrigation

Irrigation channels fall into two main types. There are large concrete lined channels which are deep, and destroy sites which they cut through (Figure 3-19). If archaeologists are present (which does not often happen) this may allow the discovery of buried sites, or the investigation of a cross-section of a site without time-consuming excavation. Nonetheless, it is extremely destructive. These major channels are rare, and usually created as part of a planned irrigation system resulting from the creation of a major dam. There is one in the Tell Beydar area, leading from the West Hasseke Dam (Chapter 5, Figure 6-53 and Figure 6-54, p254), but none around Carchemish.

FIGURE 3-19: DIGGING OF A MAJOR IRRIGATION CHANNEL, IRAQ JAZIRAH 1985[26]

A site recorded during the Tell Hamoukar survey (THS), to the east of Tell Beydar, demonstrates some of the problems. THS 8 is a Halaf site which

> *"lay in the middle of a large fallow cotton field, which had eradicated its edges. Because the process of making the irrigation furrows had destroyed the mounding of the site, masked the lighter colour of the anthropogenic soils and reduced sherd visibility, it is possible that even intensive field walking might have overlooked this site"* (Ur 2010b: 44).

The site was only discovered due to its visibility on early Corona imagery, prior to the digging of the channel. It is therefore of concern that surveys which do not use imagery in their planning now risk missing many sites.

[26] Photo courtesy of T. Wilkinson

The second form of irrigation channel is more minor, and more common. Small irrigation channels are dug by farmers leading from wells or the local river to the fields (Figure 3-20). These are much less destructive, being shallower and narrower. Nevertheless, they can still result in damage to the upper levels of a site, and if it is a shallow site, can disturb whole sections. Only one potential irrigation channel was visible on early Corona imagery (see Chapter 6.7.4, Figure 6-56, p256), perhaps due to the low resolution, as Perthes (1995) and Hole (2006) suggest they the land was irrigated at the time of image acquisition.

FIGURE 3-20: SMALL IRRIGATION CHANNELS AT TBS 10[27]

The irrigation channels are visible as straight dark green lines, indicated with red arrows.

Cotton has become a particularly popular cash crop in recent years, but it is a thirsty crop, requiring intensive irrigation, particularly in the drought-ridden Jazirah. It can also require construction of small terraces to contain the water. Given the dates of imagery acquisition (Methodology Chapter 4.3, Table 4-1, p123), it is not possible to say for certain if cotton is grown in many places and therefore its effects cannot be accurately compared or estimated. As a result, the damage done by cotton irrigation is only noted if it is recorded on the field visit notes.

[27] Geoeye Image, 23 June 2010. Taken from Google Earth 10 October 2012

Dam Reservoir Beds

The final form of irrigation damage is from dams. Dam reservoir beds are not technically a form of irrigation, but that is one purpose behind dam construction. The threats described result from the dam, therefore they are recorded under irrigation for the sake of simplicity. The flooding of sites does not necessarily destroy them, but it does remove access to them. Once water recedes, sites can sometimes still be excavated, such as at Shimshara in Iraq (CZAP n.d.). However, sites in the fluctuating shoreline area (called the drawdown zone) are particularly prone to erosion, and some sites can be buried under many metres of sediment, depending on their location in the reservoir. In these cases archaeological knowledge is actually or effectively lost (Lenihan 1981).

This affects only two sites studied: TBS 2, and TBS 17, which are located within the reservoir zone of the West Hasseke dam, and which have sustained damage resulting from the inundation resulting from the filling of the reservoir. Further west, there may be sites below the new level of the Euphrates, which was raised by the building of the Tishrin Dam in the 1980s. Whilst rescue excavations (Chapter 7.2) focused on the valley floor as the area impacted most by the dam, the excavations were largely tell focused, and most of these sites are now inundated. The state of the submerged sites is unknown.

3.5.5 – Roads / Tracks

Roads take three main forms. There are small gravel tracks, or places where people drive (such as the track around TBS 25, visible in Figure 3-21) which cause only limited erosion. Over time, their use will wear down sites much as stairs are slowly worn away. These tracks are often reinforced later, or covered with large amounts of white gravel, indicating heavier use. Small tracks, particularly those which are not reinforced, cause gradual erosion, as the wearing away of the ground cover opens the land to slow dispersal by wind and water. Although the effects have not been studied in the Near East, it was studied by Kincey and Challis in British uplands in the Brecon Beacon National Park. They determined that whilst erosion depth varied considerably it was "clearly concentrated in proximity to established routes through the landscape … with a substantial proportion of the damage being in the form of small linear erosion features parallel to the mains route and often on bends in the track … braiding around track intersections represents the most severe form of erosion recorded" (Kincey and Challis 2010: 130-131). Even though the paths were only footpaths, almost half of the archaeological sites examined were affected by erosion resulting from the tracks in proximity to them.

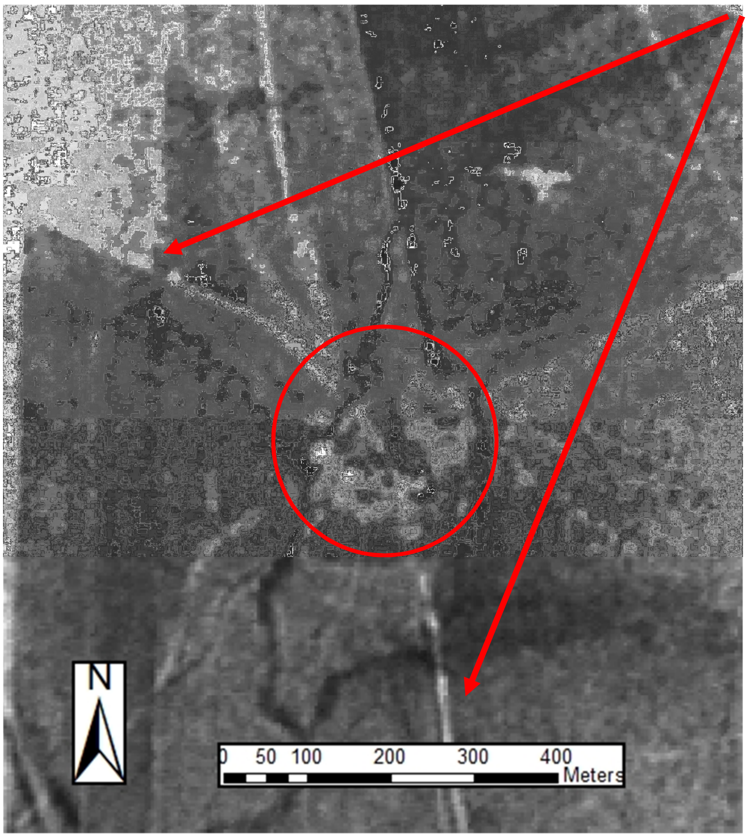

FIGURE 3-21: TRACK THROUGH TBS 25 (CIRCLED IN RED) IN 1967[28]

Increasingly, modern roads are now covered with tarmac, and older track roads are being upgraded, which causes the most damage. This change can be seen at Tell Rajab (TBS 4) (Figure 3-22). Some roads, particularly tarmac roads, cut through sites, destroying them at least to ground level (Figure 3-23). Many of the effects of construction of major roads are similar to those of development (see Section 3.5.1, and particularly the work of Davis et al. 2004). During the pre-construction phase, boreholes and trial pits are dug, usually at approximately 100m intervals along the road. As with other forms of construction, the topsoil is stripped, and upstanding earthworks, sites, or features are flattened or removed as part of the land preparation. Heavy machinery can cause pressure and compaction of soil and archaeological remains; chemically aggressive materials may be introduced, particularly if weak soil is

[28] Corona image 1102-1025df006-1_37N, standard deviation stretch, 09 December 1967

strengthened. Many sites are bulldozed for new major roads, as the cuts into them are sometimes visible. Figure 3-24 is a close-up of the side of Tell Sekar Foqani (TBS 39), showing the damage caused by the road (the whole tell is visible in Figure 3-39, p87).

FIGURE 3-22: UPGRADING OF A ROAD AT TELL RAJAB (TBS 4) BETWEEN 2004 AND 2010[29]

FIGURE 3-23: ROAD CUTTING THROUGH MOUND, ON THE ROAD FROM BRAK TO BEYDAR[30]

[29] Left: SPOT Image, 31 December 2004(?). Right: Geoeye Image, 17 August 2010. Both taken from Google Earth 20 April 2012.

FIGURE 3-24: CUT INTO TELL SEKAR FOQANI (TBS 39) FOR A ROAD [31]

The cut into the side of the tell is visible as a dark shadow next to the road.

In these cases, excavation under the road is impossible, so how much of the site remains, if any, is unknown. Once the road is in place, it may need repairs, potentially causing further ground disturbance. Existing materials may need to be strengthened or replaced. Road surface repair can range from simply adding a new coat of bitumen and chippings to total reconstruction. Fortunately it is rare for the original excavation level to be disturbed unless road widening is occurring (Davis et al. 2004).

Although not explicitly recorded, it should be noted that roads effect further damage as they improve access to an area. Places that were once remote and rarely visited become accessible by people. Heavy machinery can be brought in, and areas utilised more intensively.

3.5.6 – MINERAL EXTRACTION / QUARRYING

Although fortunately not common, when it occurs quarrying is extremely destructive, over time often resulting in total loss of the site. Even if the quarry itself does not reach a site, it can still have a highly detrimental effect. Pryor, working on a Neolithic ditch

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30 Photo copyright: the author, July 2010

31 Geoeye Image, 23 June 2010. Taken from Google Earth 20 April 2012

enclosure at Etton in 1983, noticed that when quarrying started near the excavation site, the engineers drained the water from the quarry, and also from his site, leading to the desiccation of the previously well-preserved wooden remains (Pryor 2008: 191). The vibrations of the heavy machinery can also cause damage to more fragile unexcavated remains.

Quarrying is known from only a few sites in the Land of Carchemish Project survey area, and is discussed in more detail in Chapter 8.7.6 (p376). Two of the quarries are small and localised (see Chapter 8, Figure 8-45 and Figure 8-46) but the third is an industrial quarry on the edge of a site, which will obliterate the site when it reaches it.

3.5.7 – Military Damage

It was originally intended to extend this study into Iraq, and also to include selected case studies where this would be examined. Due to constraints of space, these studies were not included in the final draft. Military damage is only recorded on one case study site – there were mines on the tell at Carchemish whilst this study was undertaken: these are discussed in Chapter 8.7.7. Given the rural nature of the areas studied, it is unlikely that any further military damage had occurred, *as of 2010*. It is acknowledged that due to the current conflict in Syria, this situation is likely to have changed, but this would extend the remit of the study beyond practical boundaries. For work on military damage to sites in Syria (see Brusasco 2012; Cunliffe 2012a; b; c).

The threat posed by mines is complicated – in and of themselves they are not a big threat.

> *"AP [anti-personnel] mines are usually installed at depths of 0 to 25 cm with dimensions from 3 cm to 15 cm. AT [anti-tank] mines could be buried deeper than 25 cm, sometimes up to 50 cm or more. But these mines usually have larger dimensions than shallowly buried mines. In the case of non-metallic landmines, their burial depths are typically from 0 to 25 cm in a clayey soil due to their effects of explosion whereas they could be larger than 25 cm, even up to 50 cm in a sandy soil. Therefore, the maximum detection depth can be 25 cm in clayey soil and in sandy soil, the maximum depth is 50 cm"* (Sai et al. 1998: 3).

Most mines, however, are close to the surface: their burial causes slight pitting to the very uppermost levels of the site, but they represent a far greater threat. If they detonate, the site would undoubtedly be seriously damaged. They also represent the possibility of armed combat and the ensuing gun and shellfire, and the possibility of tanks and tank emplacements which can cause serious damage to a site (Cunliffe 2012a).

3.5.8 – Bulldozing

Bulldozing is an increasingly common threat to sites across the Middle East. After aerial flights over Jordan, Kennedy and Bewley remarked

> "*what is surprising is just how ubiquitous the bulldozer is, no matter how distant one is from the few major centres of population*" (2010: 193).

It is also a complicated form of damage: it almost never occurs by itself, but serves another purpose. Common causes are the extension of fields or the creation of terraces, often for cotton. At Tell Jerablus Tahtani (LCP 22), bulldozing has been used for both these purposes. Figure 3-25 shows bulldozing into the side of the tell to create three levels of cotton terracing. Figure 3-26 shows the bulldozing to extend the fields, slightly further round the tell. Figure 3-27 shows the clear appearance of both of these on imagery. At Carchemish, bulldozing has taken place along the western ramparts to extend the arable fields. Bulldozing is also probably a precursor to the development of major roads, but as this is hard to determine, it is only recorded if it is absolutely certain. In Jordan, it has been used to make way for modern olive production (Kennedy and Bewley 2010).

There is no simple way to see bulldozing on the majority of sites, or to determine how much damage it has caused. The main indicator is often an otherwise inexplicable increase in the distribution of the reflected feature, which can be attributed to other causes (as will be discussed shortly). Using bulldozing recorded during the field visits as the benchmark, either a great many sites have been bulldozed, (which is not impossible), or from above, sites which have been heavily ploughed often show the same levels of disturbance.

FIGURE 3-25: THREE LEVELS OF COTTON TERRACES IN THE SIDE OF TELL JERABLUS TAHTANI (LCP 22)[32]

FIGURE 3-26: BULLDOZING INTO THE SIDE OF TELL JERABLUS TAHTANI (LCP 22) TO EXTEND THE FIELDS[33]

[32] July 2010. Photo copyright: the author

When bulldozing is marked as a damage source, it is therefore inferred from a combination of classes of evidence. These include: the field notes; visible cuts into a site with shadows indicating a drop (such as at TBS 39 – Figure 3-24); an abnormally straight line along the edge of a tell or field; and / or a visible spread of cultural soil. Figure 3-27 shows the extension of a field at TBS 11.

FIGURE 3-27: BULLDOZING TO EXTEND FIELDS AT TBS 11[34]

The field is indented into the mound of the village, and the edge is artificially straight.

TBS 16, on the other hand, is recorded on the field notes from 1997 as a group of low mounds. However, a note from 1998 states part of the site has been bulldozed: the extent is not mentioned. The site can be located by comparing the field visit sketch map (Figure 3-28) to the Geoeye image (Figure 3-29). However, almost no trace of the site is visible: the plough lines are largely undisturbed and there is no distinctive soil colour. Comparison also shows substantial changes to the landscape. The major road to the side of the mounds is not marked, and the wadi which cuts above mound A is now ploughed out. It may well be that most of the site has been bulldozed as part of

[33] Photo July 2010. Copyright: the author

[34] Geoeye Image, 17 August 2010. Taken from Google Earth 20 April 2012

the redevelopment of the landscape. (On close examination, the dark line (marked by an arrow on Figure 3-29) by the road is probably a shadow where the road has dug through part of the mound, suggesting that part C of the mound is still present. There is also a slight change in the plough lines, marked by the second arrow, which also suggests some part of the mound still remains).

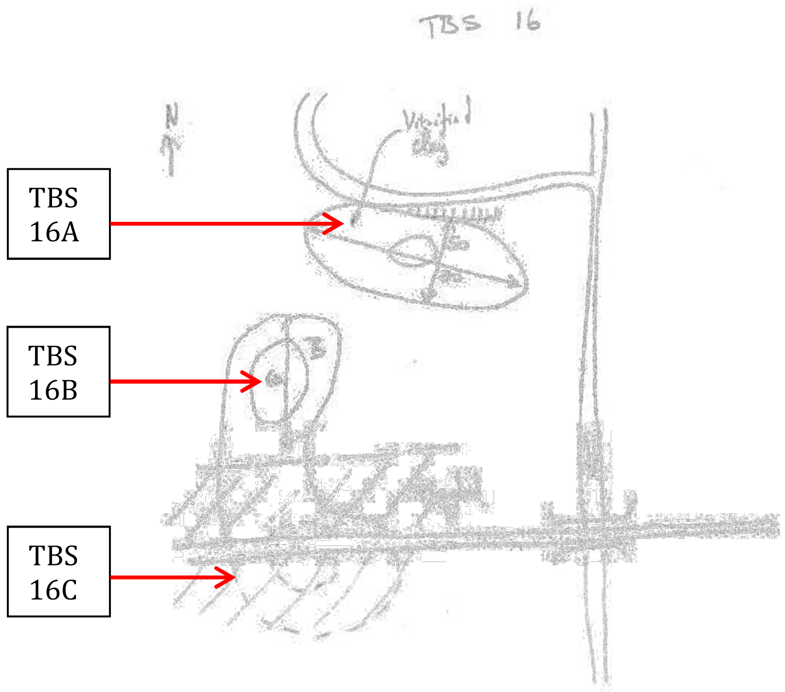

FIGURE 3-28: SITE PLAN FOR TBS 16 FROM FIELD NOTES (1997)

FIGURE 3-29: BULLDOZING AT TBS 16[35]

35 Geoeye Image, 17 August 2010. Taken from Google Earth 20 April 2012

This interpretation of the dark line is supported by the interpretation of site TBS 74 (Figure 3-30). According to the field notes (1998), most of the site is bulldozed except a strip along the road. On the imagery, this shows up as a darker embankment line, similar to that seen in Figure 3-29.

FIGURE 3-30: BULLDOZING AT TBS 74, FIELD VISIT SKETCH MAP AND GEOEYE IMAGE[36]

Bulldozing can also be identified from the spread of cultural soil. AT TBS 31, for example, the field notes record that "*Area B is an area of very low indeterminate mounding to S of village and partly destroyed by extension of irrigated fields*" (1997). The dark areas are depressions which have retained moisture. On the SPOT image, a spread of cultural material, presumably the bulldozed area, is visible in the southern field (Figure 3-31). When compared to the 2010 Geoeye image (Figure 3-32), the cultural soil is no longer visible, and the area, even the moisture-filled depression, has been heavily ploughed. The field notes also refer to an abandoned village on the mound. There is no trace of an old village: it appears new structures are present, however. It is possible that the old village has also been flattened to make way for the new structures.

[36] Geoeye Image, 23 June 2010. Taken from Google Earth 20 April 2012

Figure 3-31: Bulldozing at TBS 31 on a SPOT Image[37]

The possible area of bulldozed soil is visible as a paler brown area against the dark brown soil. The site appears to extend past the road.

Figure 3-32: Bulldozing at TBS 31 on a Geoeye Image[38]

The area of pale dispersed soil to the south is no longer visible. The part of the site which may have extended past the road is now ploughed, as is the eastern section. It is possible parts of the site have been bulldozed.

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[37] SPOT Image, 31 December 2004(?). Taken from Google Earth 20 April 2012

[38] Geoeye Image, 23 June 2010. Taken from Google Earth 20 April 2012

The damage caused by bulldozing is often discussed as once it occurs there will be nothing left for archaeologists to examine and the cultural record is gone forever. However, it is (fortunately) not that simple. For example, (Lyonnet 2000) visited Tell Jamilo in the late 1980s, and recorded the height of the mound at 6m. In the later Oriental Institute field visits, bulldozing was recorded on 2 of the small low mounds around the tell. On mound D (TBS 59_4_0), the field notes state "*according to Joseph, local landowner, this was recently bulldozed. Today's height of 3m may therefore be a significant under representation*" (1998). Even after bulldozing, more than half of the cultural deposits remain (although presumably in a disturbed state) (Figure 3-36, p86). This may even prove to be an advantage for archaeologists, as they can more easily access earlier layers that would otherwise require careful excavation. However, both surveys agree the mound is Late Assyrian with a trace amount of Late Bronze Age pottery: in this case the cultural deposits have been destroyed with no silver lining of accessible earlier information.

Further complications include the fact that the visible presence of dispersed soil marks on imagery does not guarantee bulldozing. The tell site SHR 97 in Philip's Homs survey, for example, shows a dispersed deposit on satellite imagery and field visits confirm that part of the tell has been removed by bulldozing (Beck 2004: 338). Whilst it was hoped this would provide a reference signature for other bulldozed sites, it turns out the situation is more complicated. At TBS 54, for example, the western half of mound B (TBS 54_2_0) was bulldozed by the time of the field visits. The 2010 imagery shows a lot of dispersed cultural soil around most of the mounds (Figure 3-33), and in particular, the eastern half of mound B shows more evidence of cultural material. However, as a bulldozer has already been used in the area, it is more likely that one could be used in the future to flatten the rest of the site – clearly at least one local farmer had access to one, and was happy to use it.

However, on examining the area of mound A more closely, a mound distinguished by its height appears to still be visible, with the grey soil that is usually indicative of anthropogenic deposits dispersed around it. It could be partly bulldozed; it could be dispersed by ploughing; it could be a natural underlying component of the soil which has the same characteristics as cultural material – it is impossible to tell without a field visit and perhaps excavation.

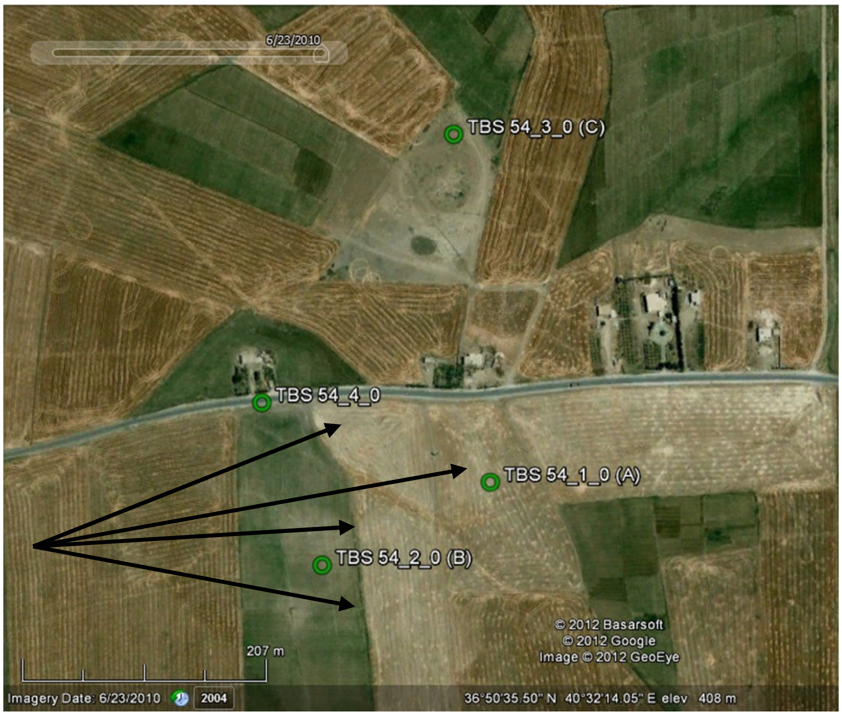

FIGURE 3-33: DISPERSED SOIL AT TBS 54[39]

FIGURE 3-34: CLOSE UP OF TBS 54_1_0 (MOUND A)[40]

[39] Geoeye Image, 23 June 2010. Taken from Google Earth 20 April 2012

At some sites it is likely that bulldozing has occurred, even though there is no mention in the field visits: as this section demonstrates bulldozing can be hard to identify, particularly if the site is under dense crop cover. Although it cannot be confirmed, there are many mounds where no height was visible and it is these which may be affected. For example, at TBS 63, there is no record in the field visit notes of bulldozing, but the grey soil mark associated with cultural material is clearly present (Figure 3-35), and most of the plough lines are undisturbed in those locations. However, a soil mark alone is not enough to record a site as bulldozed, even tentatively, as this would artificially inflate the counts of damage.

FIGURE 3-35: CULTURAL SOIL AT TBS 63[41]

The cultural soil appears grey on satellite imagery.

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[40] Geoeye Image, 23 June 2010. Taken from Google Earth 20 April 2012

[41] Geoeye Image, 17 August 2010. Taken from Google Earth 20 April 2012

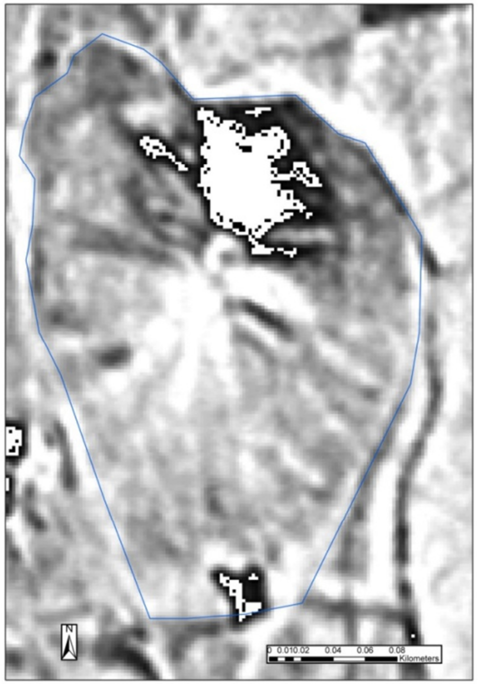
In some cases the bulldozed soil confuses the issue still further. At TBS 59, for example, according to the field notes (1998), the soil from the bulldozed mound (59_D/ 59_ 4) was dumped nearby. A decade later, this soil is still visible on satellite imagery (Figure 3-36), showing the same soil reflectance pattern as the mound it was removed from.

FIGURE 3-36: BULLDOZED SOIL AT TBS 59_4_0 (MOUND D)[42]

The cultural soil appears grey on satellite imagery. The bottom arrow indicates TBS 59_4.   The top arrow indicates where soil from the bulldozed part of the site was dumped.

Bulldozing causes one further form of damage: erosion and potential collapse. Many large tell sites are trimmed by bulldozing: for example at Tell Sekar Foqani (TBS39) (Figure 3-37, Figure 3-38 and Figure 3-39), large parts of the tell have been removed, as can be seen by a comparison between 1968 and 2010. This in turn can cause severe erosion: the shape of a tell is the result of thousands of years of erosion until a form of equilibrium is reached (see section 3.5.18 – Natural Erosion). Removing a part of the tell will expose the bottom to heavy rain. Mudbrick conservation studies have shown that water running along the bottom of mudbrick walls, such as those exposed by sectional bulldozing, is extremely damaging, undercutting them and causing collapse (Cooke 2010; Jaquin and Augarde 2012; Jaquin 2008; Keable 1996; Walker et al. 2005).

[42] Geoeye Image, 17 August 2010. Taken from Google Earth 20 April 2012



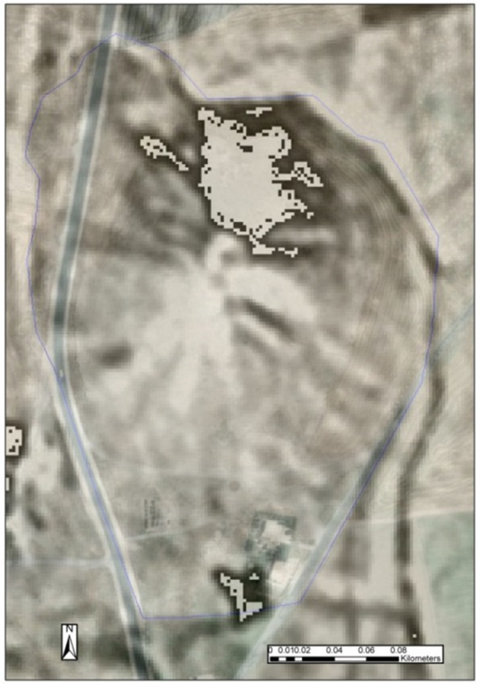


FIGURE 3-37: (LEFT) TELL SEKAR FOQANI (TBS 39) WITH BOUNDARY

FIGURE 3-38: (MIDDLE) TELL SEKAR FOQANI (TBS 39) 1968 WITH 2010 OVERLAID

FIGURE 3-39: (RIGHT) TELL SEKAR FOQANI (TBS 39) IN 2010, WITH BOUNDARY[43]

[43] Left: Corona Image, 1105-1025DF056-6_37n, standard deviation stretch, 03 November 1968
Middle: Right overlaying Left
Right: Geoeye Image, 23 June 2010. Taken from Google Earth 08 October 2012

Winter rain will undercut the tell, leading to further collapse. It has not been possible to confirm if this has happened yet in Syria, but Tell Hammeh in Jordan, which has been partly bulldozed, is apparently in the early stages of partial collapse (Dr. Veldhuijzen, *pers. comm.* 2012).

Whilst bulldozing is clearly highly damaging, it is not the clear cut destruction usually described by archaeologists, and is in fact extremely complex. The damage caused is unique to each site, and whilst regional trends may emerge, further work is clearly needed to understand its effect.

3.5.9 – Water Erosion

Water erosion, in this case, specifically refers to the damage caused by *running* water, when sites are next to water bodies, as mud-brick is easily damaged by flowing water. At Carchemish, for example, large stone walls were built which could have been defences to protect the site from the extreme floods of the Euphrates, or have formed an extension of the outer wall of the site (Figure 3-40). Damage also occurs from rainwater, but this is dealt with as natural erosion (Section 3.5.18), as it is harder to differentiate between damage caused from wind erosion and rain water erosion.

Figure 3-40: Possible Flood Defences at Carchemish, July 2010[44]

[44] Photo courtesy of the LCP Group

The effects of water on mudbrick are startling, and occur quickly. Many sites were built next to wadis (many of which only flowed for part of the year). Over time these water courses have eroded parts of the sites situated next to them. At Tell Rajab, for example (TBS 4), the field notes record "*Steep N-facing slope appears to have been heavily trimmed and eroded by Wadi Aouej*" (1997). Both the wadi and the steep, eroded north face are clearly visible on the satellite imagery (Figure 3-41). However, erosion is not always this obvious and is sometimes difficult to determine on imagery, due to the diffuse appearance of sites on imagery. A site next to a watercourse cannot be assumed to be eroded simply due to proximity. The depth (and therefore vertical distance from the site) is hard to determine on imagery. Many watercourses have also moved over the years, and their traces eroded or ploughed out (as discussed in Section 3.5.2 - Agriculture). A site which does not appear to be located by water now may once have been near a regular wadi. Many dried out wadis are particularly hard to detect, even though they may have dried out only recently. As a result, water erosion is only recorded if it is mentioned in the field visit notes or if it definitely cuts through part of the site (where site boundaries are clearly visible, e.g. tells).

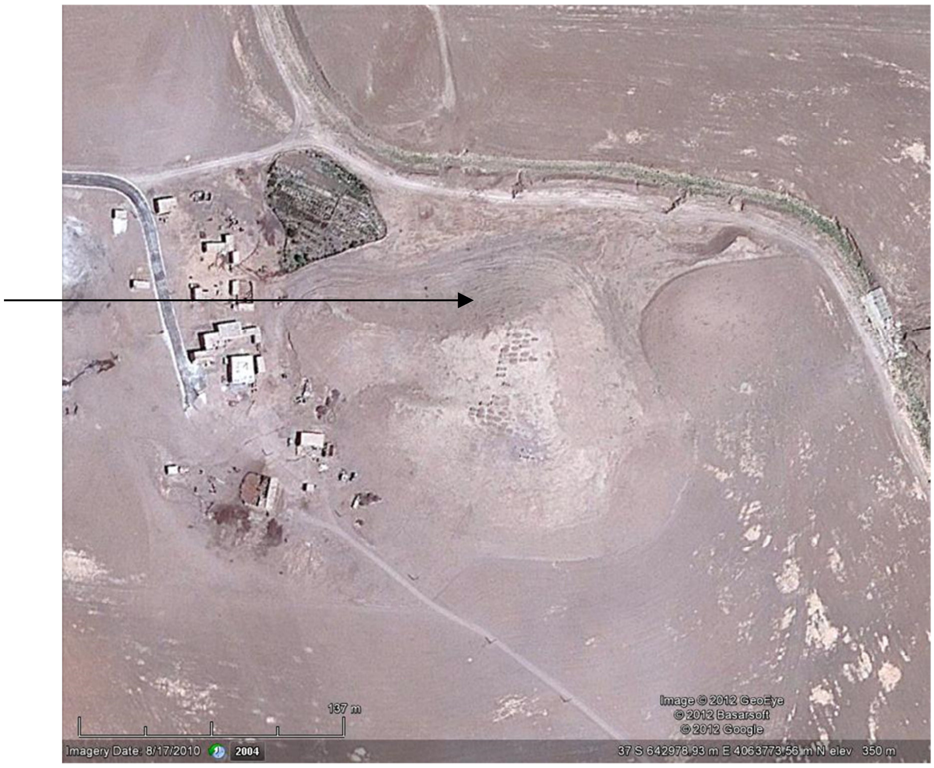


FIGURE 3-41: NORTH SLOPE OF TELL RAJAB (TBS 4) ERODED BY WADI 'AWAIDJ[45]

[45] Geoeye Image, 17 August 2012. Taken from Google Earth 08 October 2012

Water erosion is also responsible for the burial of sites under re-deposited sediment. This is discussed briefly in Section 3.5.18 – Natural Erosion, as a facet of colluviation. As it is the wadis which are visible on imagery, and which are responsible for the erosion, this process is attributed to the cause Water Erosion. However, it is only recorded as a current threat if it is noted on the site visits, and the water source appears to still be flowing.

3.5.10 – Visitor Erosion / Vandalism

This category covers graffiti, and the destruction which can be caused by visiting sites without taking proper care. Only large scale damage is detectable, and even then only on the highest resolution imagery. In fact, visitor erosion is only detectable on one site via satellite imagery (see Chapter 6.7.8, p267), although field visits also recorded that parts of a small site in the LCP had been cleared and the resulting cairns partially masked the site (Chapter 8.7.10, p383). However, field visits to other heritage sites revealed that it was an increasing problem: even the World Heritage site of Crak des Chevaliers had traces of graffiti (Figure 3-42 and Figure 3-43). Others were covered in litter (Figure 3-44). At Bosra (a World Heritage Site) and Apamea (a tentative World Heritage Site), visitors had worn down paths to reveal unexcavated mosaics, which were then at risk of damage (Figure 3-45). As most of this damage is not detectable via imagery, it is under-recorded in this study, but should not be overlooked.

Figure 3-42: Graffiti on the Walls of the World Heritage Site Crak des Chevalier[46]

[46] Figure 42 to 45 – photo copyright: the author, July 2010

FIGURE 3-43: DRAWING ON THE WALLS OF MASYAF CASTLE, JULY 2010

FIGURE 3-44: RUBBISH AT HALIBIYAH

FIGURE 3-45: VISITOR EROSION REVEALING UNEXCAVATED MOSAIC AT APAMEA, JULY 2010

3.5.11– *Archaeological Excavation*

It is an oft-repeated adage that excavation is destruction, and as a result it is listed here as a c-transform affecting sites. Only five sites have been excavated in the survey areas:

- Tell Beydar (TBS 1) (Excavations at Tell Beydar were conducted from 1992 until the outbreak of the conflict. Publications are extensive. (For examples, see Lebeau and Suleiman 1997; 2003; Lebeau and Suleiman 2007). A more extensive bibliography can be found on the excavation website[47]).
- Tell Jerablus Tahtani (LCP 22) (Peltenburg 1999; Peltenburg et al. 1997).
- Tell Amarna (LCP 21) (Tunca 1999; Tunca and Molist 2004; Valdés Pereiro 1998).
- Wadi Amarna (LCP 19) (Cruells 2004; Tunca and Molist 2004).
- Carchemish (LCP 46), excavated by the British Museum between 1878-1881, and then again between 1911-1914 under D. G. Hogarth. A final season was undertaken by Woolley and Guy in 1921 (Hogarth 1914; Woolley 1921). (It should be noted that excavations recently re-started on the Turkish side of Carchemish outside the LCP survey area (Marchetti 2012). As will be discussed in Chapter 7, these have been excluded).

Woolley and Guy, in particular, excavated the outer town of Carchemish, removing some of the Roman levels to examine the earlier plans. Some of their excavations are still visible today: Figure 3-46 shows Woolley's map overlying a 2009 satellite image - excavated houses and streets are still visible, as is the south gate. Had we not known about the early excavations at Carchemish, for example, it would have affected current interpretation of the remains. Excavations can also lead to subsequent site damage: Tell Jerablus Tahtani and Tell Amarna, for example, were not backfilled after excavation due to constraints of time and money, and are now at risk from erosion.

[47] Tell Beydar: Bibliography. Available at: http://beydar.com/index.php?lg=16&index=15 [Accessed 05 January 2013]

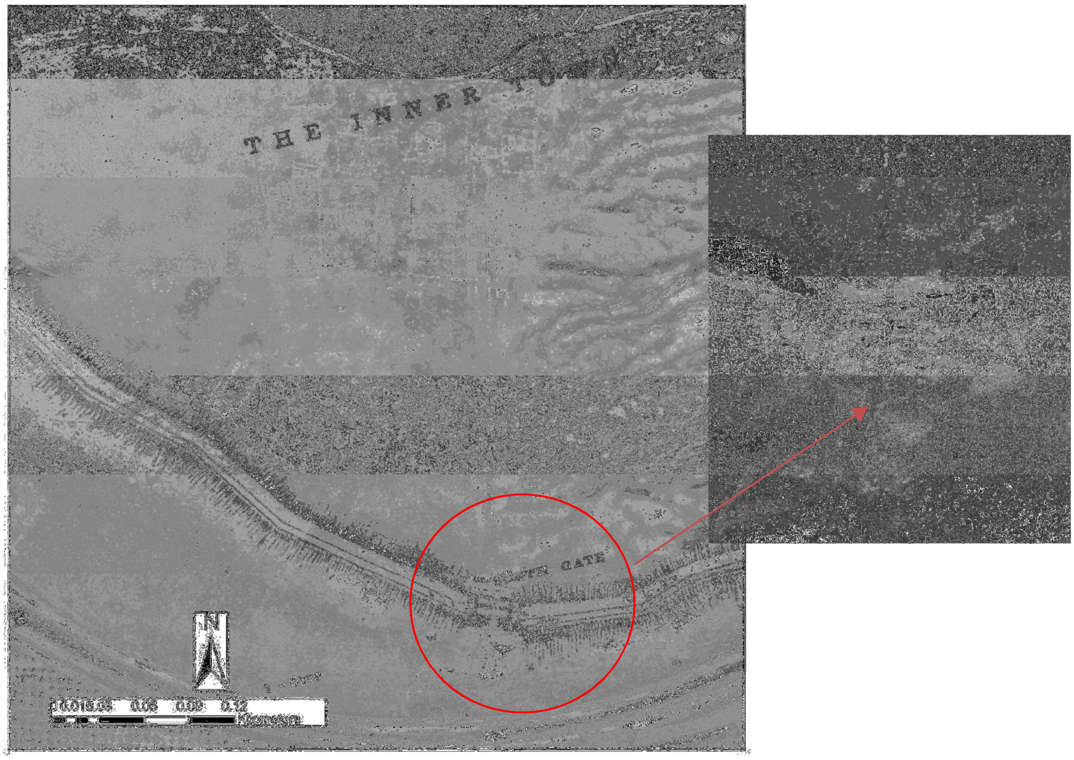


FIGURE 3-46: THE SOUTH GATE ON WOOLLEY'S MAP (1921) OVER A GEOEYE IMAGE[48]

Excavation is included to acknowledge the destructive role it plays in the life cycles of sites and is included for the sake of completeness. However, it is intentional, planned and the resulting information is used for the benefit of the wider scientific community. As a result, it will rarely be discussed further in either of the case study chapters.

3.5.12 – LOOTING

Looting is an increasing global problem, and satellite imagery may in fact offer one of the best opportunities to monitor it. As will be discussed in more detail in Methodology Chapter 4.1, Stone (2008) tried to develop statistical methods to examine the extent of looting in southern Iraq, and Lasaponara and Masini (2010) tested complex statistical methods in Peru. However the use of satellite imagery to monitor looting is an effective technique even without complicated statistical algorithms (for example, Van Ess et al. 2006).

Looting in the case study areas remains small scale compared to the extensive site destruction caused by looting in Iraq monitored by Stone: however anecdotal evidence from before this study began suggested it was increasing. Figure 3-47 and Figure 3-48

[48] Geoeye Image, 3801419_pan_001, 10 November 2009

show a looters hole at Tell Sha'ir Sajur (LCP 38). It is some 4.5 m deep, and was deeper than in the previous season (Prof. Tony Wilkinson, *pers. comm.* 2010). Other features were also damaged by looters. Figure 3-49 shows a wine press that was recorded in the 2009 season, and destroyed by the return visit in 2010.

FIGURE 3-47: LOOTERS' HOLE AT TELL SHA'IR SAJUR (LCP 38), JULY 2010

FIGURE 3-48: DEPTH OF LOOTERS' HOLE AT TELL SHA'IR SAJUR (LCP 38)

FIGURE 3-49: DESTROYED WINE PRESS, JULY 2010[49]

[49] All photos of looting copyright: the author

New holes are visible on imagery as small dark circles surrounded by whitish circles of up-cast soil. As time passes, the up-casts will fade, and the hole will fill with sediment, causing the sharp, distinctive edge of the holes to blur into larger, less dark areas. This can be seen at Tuttul (Tell al-Bi'a) near Ar-Raqqa which was looted in the mid nineteenth century (Figure 3-50 and Figure 3-51). Large areas of looting are still clearly visible. Not all looting holes found on the field visit to Tell Sha'ir Sajur were visible on satellite imagery: some of the smaller holes, for example, were in the sides of the tell, and were invisible from the perspective granted by the angle the imagery was acquired at. Another shallow hole was hidden by vegetation (Figure 3-52). This suggests that the true amount of looting recorded on imagery is under-recorded.

FIGURE 3-50: TUTTUL (TELL AL-BI'A) ON 2011 SATELLITE IMAGE[50]

Area of 19th century looting at Tell al-Bi'a, indicated by the red circle.

[50] Quickbird Image, 16 April 2011. Courtesy of the Global Heritage Fund

FIGURE 3-51: EXCAVATIONS AT TUTTUL (TELL AL-BI'A) LOOKING FROM THE WEST TO THE NORTH, HISTORIC LOOTING VISIBLE IN DISTANCE[51]

FIGURE 3-52: SHALLOW HOLE IN THE SIDE OF TELL SHA'IR SAJUR (LCP 38) MASKED BY VEGETATION, JULY 2010[52]

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[51] Photo copyright: Bertramz, Wikimedia Commons

[52] Photo copyright: the author

(Smaller, partially infilled looting holes are harder to distinguish, and are visible as regular patches of darker soil which can be easily confused with mudbrick excavations. If it is unknown for what purpose the pit was dug, they are recorded as Pits (Other) (see Section 3.5.17). This could also lead to the under-recording of looting.)

3.5.13 – Mudbrick Pits

Many local residents dig into the side of tells to extract mudbrick (*libn*) for re-use. Using the field survey notes as a guide to interpreting the imagery, these holes are distinctive from looting holes in that they are larger, shallower, have far less distinctive edges, and are always found on sites near settlements (Figure 3-53), whereas looting holes are usually found on more remote sites. However, it is only possible to determine the purpose of these larger pits using the field notes. (As in the case of looting holes, if the purpose of the hole is unknown, it is recorded as Pits (Other) (Section 3.5.17).

Figure 3-53: Mudbrick Excavations at Tell Ghazal Foqani (TBS 50)[53]

[53] Geoeye Image, 23 June 2010. Taken from Google Earth 15 November 2010

3.5.14 – Dumping Pits

These pits are often only possible to interpret using the field visit notes, as they are hard to distinguish from mudbrick pits. They are usually around the base of tells, and are a more regular shape. They are less common than the other forms of holes discussed but can still cause substantial damage to the buried layers of sites. It is more common for local people to use pre-existing pits for waste storage, rather than to create them, although it is known. There is a very large dumping pit in the base of the mound of Koulliye (LCP 50), for example: its size suggests it was dug for a different (unknown) purpose, although field notes (2009) indicate the villagers expanded it between site visits (Figure 3-54 - note the scale).

Figure 3-54: Dumping Pit at the Base of Koulliye (LCP 50)[54]

Smaller pits, however, can be very hard to detect on imagery. At 'Ain al Beidar (LCP 10), for example, field visit notes report a fairly substantial hole in the NW base of the mound (2009).

> *"Site revisited on 23rd May 2009 for possible LC/EBA sherds. In comparison with the last visit in March 2008, a dumping pit has been dug (enlarged ?) (approx. 3,5mx2m) on the NW base of the mound (site 10 area D). The bottom of this pit is found at least 1,5m deeper than the actual surrounding fields (the actual deepness not measurable because of dump). Architectural features (at least 4 walls: 2 of mudbricks, 2 of stones) are visible on the S and E sections of the pit. The foundation of at least one of the stone wall is located deeper than the surrounding field."*

[54] Geoeye Image, 22 September 2009. Taken from Google Earth 13 February 2013

As can be seen from Figure 3-55, no hole is immediately visible, although the arrow indicates a hole of the correct approximate size, but higher than would be expected.

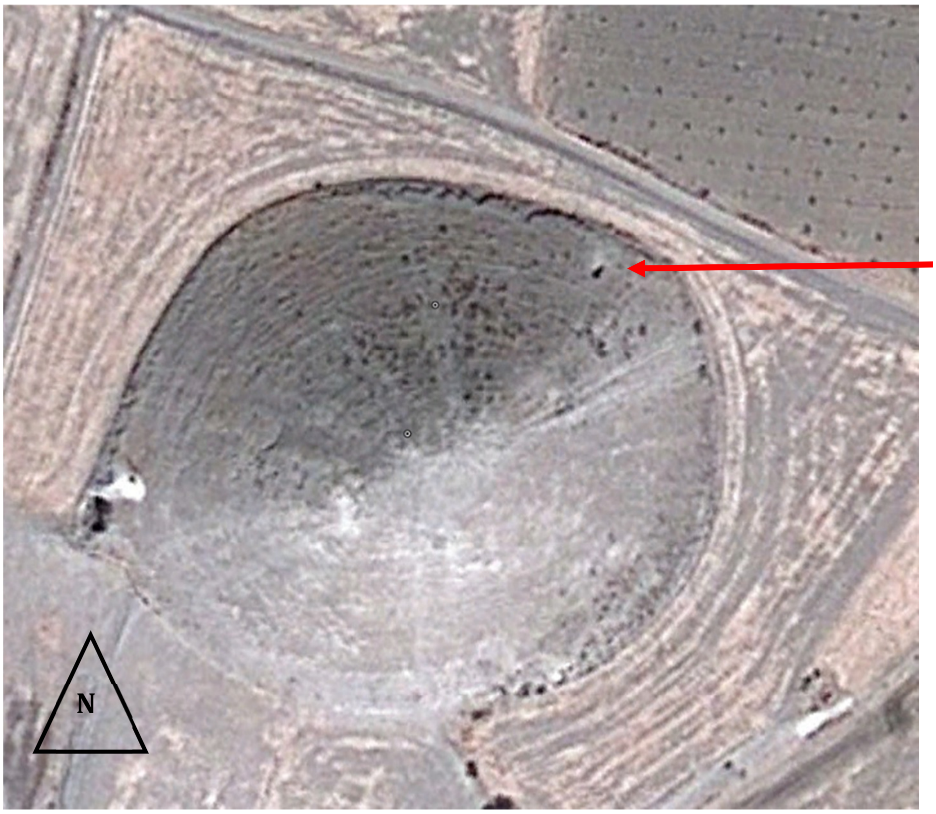

FIGURE 3-55: THE POSSIBLE DUMPING PIT AT 'AIN AL-BEIDAR (LCP 10)[55]

3.5.15 – CUTS

The term 'Cuts' is often used in an indeterminate fashion in the field visit notes. In some cases it seems to refer to mudbrick extraction pits, but in others, it seems to refer to bulldozing cuts or cuts for roads. As a result, cuts are only used as a damage term if no other cause, such as roads (seen in Figure 3-24) is apparent.

3.5.16 – GRAVE PITS

Cemeteries are primarily present on tells in the Tell Beydar survey area. In the Land of Carchemish area several cemeteries have been recorded on flat sites, such as Serai, LCP 18, a "lower settlement near the junction of the Wadi and the Euphrates, beneath the cemetery" (Figure 3-56). The number of graves varies from just one or two graves (Figure 3-57), to as many as can fit onto the site (Figure 3-58). Many tell sites came into use as cemeteries when the area was resettled after World War II, as the land was

[55] Geoeye Image, 22 September 2009. Taken from Google Earth 13 February 2013

free, and exempt from burial tax. This practice was made illegal in the 1990s, but the graves themselves are, of course, still sacred, and cannot be touched, providing inviolate protection to the sites, but restricting archaeological study. Graves are only visible on the highest resolution imagery, so comparative study between the 1960s and the modern day is not possible, but on some recent imagery, it is possible to count an increase in graves (Figure 3-59).

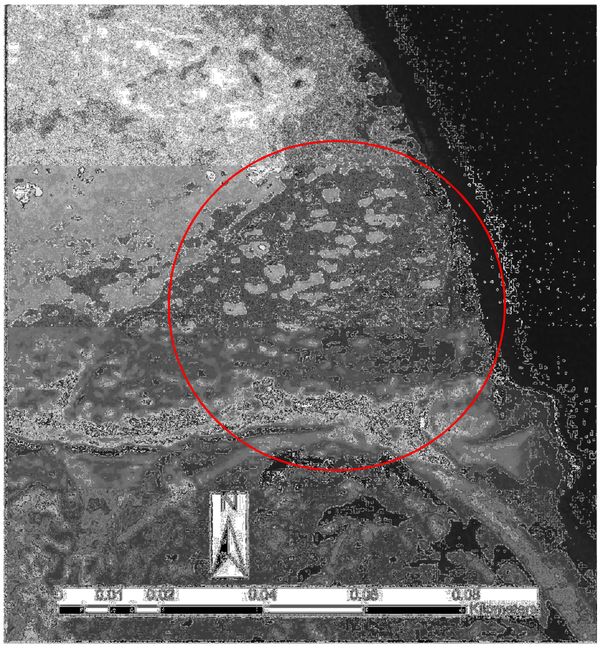

FIGURE 3-56: FLAT SITE (LCP 18) UNDER A CEMETERY[56]

FIGURE 3-57: TWO GRAVES ON TBS 35[57]

[56] Geoeye Image, 3801419_pan_001, 10 November 2009

Figure 3-58: Cemetery on Unknown Tell on the Edge of Hasseke, July 2010[58]

Figure 3-59: Increase in Graves at Khirbet Seraisat (LCP 1) 2003 - 2009[59]

3.5.17 – Pits (Other)

This covers pits which are visible on imagery but whose purpose is unknown, or which are so rare that another category would be redundant. For example, gravel extraction pits were only recorded once in the entire study.

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[57] Geoeye Image, 23 June 2010. Taken from Google Earth 15 January 2012

[58] Photo copyright: the author

[59] Left: DigitalGlobe Image, 02 September 2003. Taken from Google Earth 08 October 2012. Right: Geoeye Image, 3801419_pan_001, 10 November 2009.

3.5.18 – *Natural Erosion*

Natural erosion is assumed to occur on most sites: it is a normal taphonomic process which forms part of the 'life cycle' of archaeological mounds (Rosen 1986). The effects of erosion can be significantly underestimated by archaeologists, and this can lead to incorrect assumptions about the site under investigation. Erosion has three effects. The first is the lowering of the ground level as soil is eroded away. The second is the 'lessening' of a site, as soil and archaeological deposits are blown away (aeolian deflation) or washed away from the site into the surroundings, initially creating an asymmetrical mound profile, but eventually removing the site (Kirkby and Kirkby 1976; Rosen 1986). The third is sedimentation, which results in the burial of archaeological sites under soils washed from the surrounding areas. All three will be discussed here.

Erosional and depositional regimes vary over time. They are caused by the action of rainwater and wind, but as discussed in Section 3.5.2, they are strongly exacerbated by agriculture. Fine grained sediments such as silt or loam are gradually and rhythmically deposited, while coarse grained sediments and localised gravel fans are deposited rapidly and infrequently. Their occurrence is dependent on the surrounding landscape. Soil characteristics are of paramount importance in erosion and deposition – organic content, structure, soil and water content. Soils at most risk have a low clay content (<35%). Most erodible particles are in the 100-300 micron range, i.e. medium-coarse silt (Morgan 2005). Silt rich soils such as loess, or those with a low organic content, are highly erodible, and the organic content is often further reduced by cultivation, making it hard to maintain soil structure (see Section 3.5.2 – Agriculture: Arable Farming).

<u>Ground Erosion</u>

Wilkinson (1993: 557) estimated that 1mm of dust is blown away on the North Jazirah each year, churned up by flocks and herds. This is equivalent to 10-15 tons of dust per hectare, which lowers the land surface by 3m over 3,000 years. Much of this will be replaced as sedimentation processes deposit new material: lowering of the ground will occur only in particularly open areas where wind or water flows will pick up particles and deposit nothing and where there are no slopes for sediments to run down and settle. In most areas, processes of sedimentation will raise the ground level faster than it can blow away. In the southern Euphrates region, for example, Adams (1981: 36) noted that active alluviation with little or no counterbalancing wind erosion left many mounds partially or wholly buried.

Allen (1991) determined a series of low energy, frequent erosive events which can affect archaeological sites through colluviation. They are essentially natural processes, but greatly accelerated by processes like tillage. Material is eroded by weathering processes assisted by gravity-based processes such as:

- Rainsplash – rain hits the soil with enough physical kinetic energy to cause detachment of soil particles. In intense or prolonged rainfall, the soil becomes saturated and overland flow occurs, leading to more severe erosion. This is a particular danger to mudbrick and will be discussed in more detail shortly
- Sheetwash – Once overland flow occurs, soil washes off the surface in sheets, moving both fine and coarse material. This can lead to localised channelling, called rills, especially on agricultural land, and is common in the Jazirah (Oates 1982).
- Rills – usually ephemeral channels in the soil, destroyed by the next rainfall event. They are more erosive than normal overland flow. Larger rills have been known up to 17cm deep. Whilst the largest material is normally deposited at the base of the slope, the rest can be carried much further. Particularly deep rills are called gullies.
- Gullies – large permanent rills. These have been observed in America up to 200m long, half a metre deep and 1.5m wide.

The erosion of fine particles is probably a frequent occurrence, leading to an overall decrease in soil depth on the hill crest and an increase on the valley floor, especially on the margins of slopes. Areas of soil deposition containing archaeological material will see a gradual reduction in artefact density and ultimately total burial, reflected in changes in the surface distribution. Artefact density will increase on hill crests. Further erosion will exaggerate the effects. Soil type is key to levels of erosion. In a study of the Upper Thames Valley in England, Miles (1980) noted that the gravel subsoil was easily eroded, and that the ring ditches and Iron Age fort at Cassington were most likely not visible by the late first century BC. Saxon and medieval sites were also built on earlier sites, suggesting they were not visible.

Under more energetic events, artefacts are moved. Soft items such as pottery, which weather into well rounded pieces more rapidly, are moved first. This has the serious potential to distort artefact scatters, particularly over the timescales some archaeological sites have been exposed for. Indeed, on some sites entire levels of sites are exposed or even removed (Adams 1981: 44). Severe rilling and gullying will remove artefacts. Concentrated channelling indiscriminately moves a small percentage of the ploughsoil, including any associated artefacts, which are then sorted and rearranged during deposition, or buried. A particularly deep channel, on the other hand, may reach a buried site, altering it before it has even been discovered, and ironically, enabling its discovery. (A detailed discussion of meander hydrology, and its effects on sediment load and deposition can be found in Adams 1981: 7-11).

Whilst ground erosion is a form of natural erosion only the largest gullies are visible on satellite imagery. Arable agriculture, however, breaks up the natural ground cover holding down the topsoil, opening the land to these effects. When we talk about arable agriculture, as well as the obvious disturbance caused by tractors and ploughs, amongst others, this is one of the key forms of damage. However, as the agriculture is the visible threat, this is what is recorded.

As discussed in Section 3.5.5, tracks can also cause gradual erosion: as with agriculture, the wearing away of the ground cover opens the land to slow dispersal by wind and water. Kincey and Challis's study (2010), for example, demonstrated the links between tracks and erosion in a British National Park. However, as the track is the anthropogenic cause leading to the natural threat, it is the track which is recorded.

<u>Site Erosion</u>

Most sites are susceptible to erosion damage: only the scale and speed varies. Kincey and Challis demonstrated "the erosion damage … has impacted on a number of cultural and natural sites... with definite evidence of erosion across eight of eighteen archaeological sites (2010: 131). However, many sites in the Middle East are made of mudbricks, which are particularly susceptible to erosion, and it is these sites that this section will concentrate on.

The effects of rain on mudbrick are predictable, and can be seen at excavated and reconstructed / restored sites. The durability of a mudbrick building depends largely on its ability to resist water penetration (Hammond 1973). The impact of rain on the surface causes numerous problems, leading to cracks, shearing, decomposition and collapse. Storm water in the Jazirah drains in the form of sheetwash (Oates 1982), which can also have significant effects, undercutting the bottom of walls, or causing them to collapse from above. Wet ground also leads to rising damp, which can contribute to decomposition. Mudbrick conservation theory suggests that sites should have good drainage, surface protection in the form of protective coatings, particularly on the base, or weather screens and suitably large eaves to prevent rain splash (Hammond 1973; Jaquin and Augarde 2012; Jaquin 2008; Keable 1996; Walker et al. 2005).

Walls must be repaired regularly in order to protect them, as otherwise they will degrade quickly, as can be seen at the excavated walls at Tell Brak (Figure 3-60). Figure 3-61 shows the effect of rainwater on the reconstructed walls of Tell Beydar, which were repaired annually (Lebeau and Suleiman 2007). (More detail on the degradation, restoration and maintenance of mud brick architecture can be found in Cooke 2010; Hammond 1973; Houben and Guillaud 1994; Jaquin and Augarde 2012; Jaquin 2008; Keable 1996; Walker et al. 2005; Warren et al. 1993).

FIGURE 3-60: DEGRADED MUDBRICK WALLS AT TELL BRAK

FIGURE 3-61: RECONSTRUCTED MUDBRICK WALLS BEGINNING TO DEGRADE AT TELL BEYDAR, JULY 2010[60]

[60] Figure 60 and 61 – photo copyright: the author

Damage to standing mudbrick architecture from rainwater, however, is primarily only an issue at excavated sites. Within the study areas, Tell Beydar (TBS 1), Carchemish (LCP 46), Tell Jerablus Tahtani (LCP 22) and Tell Amarna (LCP 21) are the only sites at risk from this. Water erosion of this type is still only visible on the highest resolution imagery, if at all, and so is not recorded as a quantified damage threat.

Once the upper levels of the site have degraded to a certain point, however, the site forms the classic tell mound found across the Near East. The creation and erosion of mounds follows a predictable pattern, which has been studied in detail by Kirkby and Kirkby (1976) and Rosen (1986). Each generation occupying a mound inherits the topography of the previous one, and it will inevitably be uneven throughout its use and into the period of abandonment, forming small mounds of different sizes. Rosen, developing the work of Butzer (1982) and Butzer et al. (1983), identified the following sediments which contribute to the tell's matrix: organo-cultural refuse; collapsed rubble; water-laid sediment deposits; biogenic and geochemically altered sediments, which may eventually form soil; geological sediments; aeolian sediments; and alluvial deposits. The most significant post-depositional factor was erosion, which breaks down mudbrick, smooth's topography, and modifies the slope. The angle of the slope is key to the rate of erosion, and is affected by structure, climate and stage of evolution.

Many larger mounds, for example, are fortified. Fortifications such as stone-faced ramparts are more resistant to erosion, and can act to slow it, giving the tell a distinctive concave shape. Figure 3-62 shows Tell Effendi - the outer fortification walls are visible, as are the gates through them, and the centre is concave, with the inner town acropolis rising up, marked more clearly on Figure 3-63. Tells with more advanced erosion are usually smaller and have smooth or conical surfaces (Figure 3-64 and Figure 3-65). Climate has a significant (but often under-estimated) effect on mound erosion. The effects of intensity and duration of rainfall, direction of surface run-off, frequency and duration of stages of wetting and drying, wind erosion, and freeze-thaw cycles are key. Vegetation is also important – it can inhibit erosion and stabilise slopes. In more temperate climates, tells are more overgrown, and experience less aeolian deflation and surface erosion. Drought conditions, such as those already noted in the Fertile Crescent in 2006-09, can affect vegetation levels, and so exacerbate deflation and erosion. Trigo et al. (2010: 1246) note that in semi-arid areas such as the

FIGURE 3-62: TELL EFFENDI (TBS 55)[61]

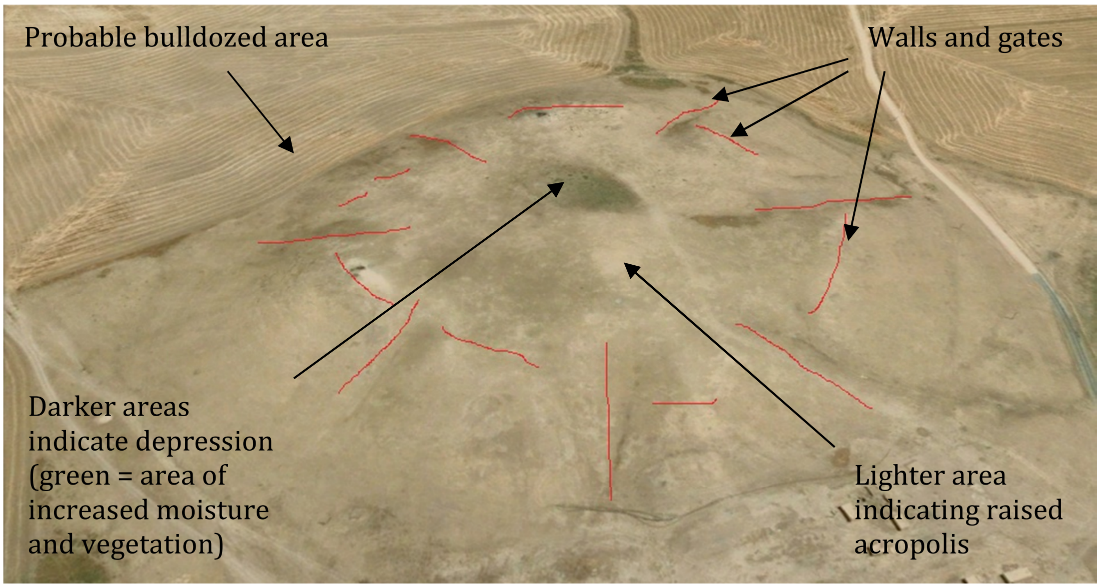

FIGURE 3-63: TELL EFFENDI (TBS 55), WITH INFERRED WALLS AND GATES MARKED[62]

[61] Geoeye Image, 23 June 2010. Taken from Google Earth 09 October 2012.

[62] Geoeye Image, 23 June 2010. Taken from Google Earth 09 October 2012.

FIGURE 3-64: KOUNDOURIYE (LCP 60) - A CONICAL TELL ON SATELLITE IMAGERY IN 2009[63]

FIGURE 3-65: KOUNDOURIYE (LCP 60) - A CONICAL TELL IN THE FIELD, 2009[64]

Fertile Crescent, "*a combined effect of lack of precipitation over a certain period with other climatic anomalies, such as high temperature, high wind, and low relative humidity over a particular area may result in reduced green vegetation cover*", which can take longer to reform than it did to reduce.

Slope erosion is complex (Kirkby and Kirkby 1976; Rosen 1986). Slope erosion in which irregularities are smoothed by abrasion results in a low gentle hill where colluvium accumulates at the base, stabilising it and decreasing the slope angle. The base increases as the angle becomes increasingly gentle. Rainwash, particularly the sheetwash noted by Oates (1982) on the Jazirah, can play a key part here. Rain runs down the slopes of the tell, removing the soil, and as the sheetwash runs past the

[63] Geoeye Image, 22 September 2009. Taken from Google Earth 09 October 2012

[64] Photo courtesy of the LCP Group

bottom it causes erosion which removes the base of the tell and undercuts it. The slopes then decline slowly as a result of soil creep, usually with some decline in height. This is dependent on the amount of rainfall. Decline is rarely uniform: factors include the location of the tell, the time of first and last occupation, the length of occupation, cultural modifications, rainfall amount, intensity and direction, sediment type, vegetation cover, presence of wadi, and length and gradient of slope. Tells are also rarely symmetrical, even before the effects of modifications like the bulldozing visible on the north side of Tell Effendi. The northwest slope is usually steeper, as it faces the prevailing wind. Vegetation is also usually denser on the north slopes due to the differences in moisture and solar radiation.

This was seen in the Jazirah:

> *"The northern slopes face the direction of the prevailing wind. This situation encourages parallel slope retreat, wherein the relatively sharp angle of the slope at the time of abandonment is maintained while the position of the slope itself gradually moves backwards. The south-facing slopes, however, are struck obliquely by wind and rain, which encourages slope decline. This process removes materials from the top and redeposits them at the base, creating a longer and more gentle slope. The two processes operate at different rates: the north-facing slopes support greater vegetation, which acts to retain the soil, while the low vegetation southern slopes offer less resistance to erosional forces. The resulting asymmetrical profile … is almost universal among simple conical mounds on the plain, but also characterizes other large mounds"*
> (Rosen 1986: 31-33 in Ur 2010b: 20).

Ultimately surface erosion can "*reduce the topographic form of small mound sites to nothing more than a surface scatter of sherds within 500 to 2000 years, depending on the mean annual rainfall*" (Kirkby and Kirkby 1976: 229). The importance of agriculture in increasing this effect must be stressed: it acts to advance erosion to the point where some sites have had their mounding completely erased. It removes vegetation, decreases soil stability, both of which increase rates of erosion, and can act to move soil off the tell.

The soil which erodes from sites has to go somewhere, usually spreading out around the bottom of the site. Wilkinson et al. (2010: 759) noted:

> *"Profile observation by Wilkinson in 1991 and French and Matthews in 1993 in the immediate vicinity of Tell Brak indicate that there can be as much as 80 cm of eroded calcitic silt and occupation debris derived from the tell mound that has aggraded on clay loam alluvial deposits … In one instance this paleosol … is equated with the main period of occupation at Tell Brak."*

This fringing area of silt can cause significant problems in interpretation on satellite imagery, leading to incorrect assumptions about the site under investigation. Bulldozing (Section 3.5.8), for example, is sometimes suggested by a spread of cultural soil deposits across an area, which may simply have occurred through natural erosion, such as in Figure 3-31 and Figure 3-32.

> *"Most sites have probably been reduced in height, since agriculture has removed the steppe vegetation that anchors the soil; sites are now much more susceptible to aeolian deflation and erosion via surface run-off ... Whether via plough or erosion, the surface assemblages of many sites have been diffused to some extent across the landscape ... It is unlikely that such movement has dramatically altered the spatial extent of surface assemblages"* (Ur 2010b: 42).

On imagery, however, the dispersion of cultural soil around a site can make it seem larger than it is, suggesting cultural deposits and relationships between mounds where none may exist. TBS 24 is discussed in Chapter 6.2.1 – The Extent of Sites in the Tell Beydar Area (p184), as an example of a site which may be larger than surveyed. However, it is also possible that the site is heavily eroded, perhaps by the wadi, which has caused an "*erosional cut downstream*" (TBS field notes 1997), and that the soil is heavily dispersed, and thus seems larger than expected. This is unlikely: it was postulated that higher light reflectance, such as is visible on the Corona imagery, is due to a combination of fine average grain size, high clay content and / or poor sorting, causing moisture loss, and leading to increased light reflectance (Wilkinson et al. 2006: 741). If this is correct, then fine particles are the most likely to be washed away completely, and wadi action is unlikely to lead to moisture loss. The potential effect of the removal of fine particles on site identification on satellite imagery is discussed in the Methodology Chapter 4.4 – Identification of Sites on Satellite Imagery (p126).

Erosion can blur site boundaries to the extent where, in some cases, it is not possible to tell if the site was composed of separate parts, such as at LCP 70, where

> *"dispersed soil from robber trenches eroding down into the wadi makes defining the site rather difficult. It is possible that there were once two distinct scatters, one around the tombs, and one further N on the hill-top proper. Any differentiation in pottery has been erased" (LCP field notes 2009).*

All of this also affects sherd density. Casana (2007) notes that as more vegetation led to less erosion, this led to a sparser pottery pickup. Rosen (1986) also demonstrated that it led to an under-representation of early periods on and off the mound, and a mixing of sherds of different periods, all of which have important repercussions for settlement patterning. Interestingly, it was also noted that if the surface was scraped just 1-5cm (rarely done in survey), the chances of finding earlier material greatly improves.

However, given the problems of site definition (discussed in Chapter 2.2), site extents are defined as they were in the field. Erosion in the sense just described is only recorded if it is noted in the field visits or excavation reports. This distinction, although increasing the accuracy of the information, will under-represent the effect, particularly on excavated sites, which should be remembered.

<u>Sedimentation</u>

Colluviation caused by sedimentation is also a problem, creating blanks in the archaeological record. This is either caused by wadi deposition of silts overlying sites, such as at Khirbet Seraisat (LCP 1), detailed in Chapter 8.7.9, or erosion from slopes leading to sedimentation on valley floors. In the case of the former, this is categorised here as "Water Erosion". In the case of the later, evidence from Allen's study (1991) suggests that, unexpectedly, valley morphology bears no relation to resultant deposits and depth. Erosional processes have been noted on slopes as shallow as four degrees. However, on particularly steep slopes, even where precipitation is low, gravity can have much the same effect (Rick 1976).

Erosion and colluviation are also not constant processes: they are dependent on the intersection of appropriate climatic conditions and agricultural levels, amongst other variables. Casana's work in the Northern Levant (2008) demonstrated that whilst Bronze and Iron Age communities occupied the area for almost three millennia, they had relatively little effect on soil erosion. Settlement intensification and the conversion of marginal upland soils to arable land in the Hellenistic and Roman Periods, (also seen in both case study areas) led to severe soil erosion when precipitation levels increased. Between 3.5 – 5m of alluvial sediments were deposited on the valley floors, forever altering the landscape and masking sites. For example, the only locus of PPN artefacts identified in a survey of the Amuq plain was in an exposed section buried 5m beneath modern floodplain (Casana 2007: 198). On the Lower Khabur floodplain, almost 2m of silty sediments has accumulated over the last 2,000 years (Ergenzinger et al. 1988) which will mask sites. Agriculture is particularly useful in cases of ground level rise, providing the means by which sites are detected. In southern Iraq, Ras al-'Amiya was almost completely submerged in alluvial deposits, but ploughed up pottery sherds were noted on the surface, leading to its identification and excavation (Stronach 1961).

Erosional processes do not just bury sites; they can assist in landscape changes by smoothing out features such as wadis, making it easier for modern machinery to open out the landscape into large, intensively farmed fields.

> *"Once [wadi] flow diminishes below a certain interval, such as one significant flow every two to three years, the wadi will fail to evacuate much of its sediment load. If ploughing takes place every year or two on the adjacent terrain, lateral ploughwash will choke the valley floor, and the wadi channel will cease to present an impediment to ploughing. As a result, ploughing will operate freely across the former wadi bed, thus re-inforcing its demise as a hydraulic feature"* (Wilkinson and Tucker 1995: 4).

Colluviation is not visible on satellite imagery, and ground levels are assumed to change as part of the on-going natural landscape cycle, so it is not recorded as a damage threat.

Finally, it should be noted that these three processes are not separate - they can all occur at the same time, and all interact with each other. Sites can be buried, and then the area eroded until they reappear, and partially eroded sites can be buried. The interrelation is a natural part of the life cycle of a site.

3.5.19 – Railways

Only one site had a railway through it – the lower town at Carchemish. This is discussed in the Carchemish Damage Analysis Chapter 8.7.18.

3.5.20 – Unknown Damage

No site is preserved in perfect condition, unchanged from the moment of its final abandonment. On some imagery, particularly lower resolution imagery such as Corona, it is not always possible to determine the state of a site. In these cases it is marked as unknown.

3.5.21 – No Damage

Although no site will survive in its entirety in perfect condition, sites are also studied in sections, and change over time is studied. It is possible that either small sections of sites will be undamaged, or that if satellite images are taken particularly close together no damage will have occurred in that time period. However, in practical terms, the only images taken that close together are the Corona images, and the DigitalGlobe 2003 and SPOT 2004 images. Neither the Corona nor the SPOT images have a high enough resolution to be certain no damage has occurred in the intervening times. As a result, the category of "No Damage" was not actually used in the study, although no change occurring between images is of course possible in any comparative sequential study.

3.6 - Site Stability

The final aspect of damage is the extent to which it is increasing. For example, if a site was under arable agriculture in the 1960s and is still being farmed in 2010, has the agriculture increased? Damage was judged to be increasing if a new damage type became visible which was not present before, or if something changed, such as the ploughing out of wadis, the removal of field boundaries and the conversion of the land to large commercialised cash-crop fields, or the conversion of a gravel track to a tarmac road, for example. Damage does not always increase, of course. In some cases, it may decrease, as will be demonstrated in the Development Section of the Tell Beydar Chapter 6.7.1, for example, where villages were abandoned and the land was turned to agriculture.

The damage caused by agriculture is an on-going threat, if not always an increasing one: it will continue to open sites to erosion as long as they are ploughed and bare. Only crop cover (or the low vegetation which is ploughed away) binds soil to sites. It has often been suggested that farming causes little damage to sites, as many sites have potentially been ploughed for hundreds of years and the sites are still present and examinable. However, the difference between a farmstead and a sherd scatter in terms of the information they provide to archaeologists is considerable.

Site extents are also affected, particularly by agriculture, affecting estimates of settlement patterning. Rosen's work (1986) also shows that, whilst it is a slow process, erosion effects significant changes to sites. We cannot say what the original form of the sites was, or what damage has already been done, but erosion, and therefore agriculture, does pose an on-going risk to sites, as do many other threats.

The following analysis only deals with threats that are still present. If a threat is no longer present on an image, it is no longer counted. So, for example, if a site had water erosion damage on Corona, but no wadi (and therefore no erosion) was present on later imagery, this would not count as a lessening of damage, as the lack of wadi is not counted at all.

3.7 – Concluding Remarks

Sites are affected by both on-going natural landscape transformations and anthropogenic threats. These c- and n-transforms, as Schiffer termed them (1983; 1987) can have catastrophic effects on the preservation of sites and the recovery rates of accurate information, which are not always accounted for in archaeological work. Some sites, the lucky few, are in what Wilkinson (2003) termed Zones of Preservation, those places with limited later occupation, where older or more fragile remains are still (relatively) undisturbed. Others are in Zones of Attrition, those highly fertile areas which have served as the foci of settlement for millennia, such as river banks and flood plains. Human activities in these areas have continuously rewritten the settlement patterns, and in turn have been overwritten by natural processes such as erosion and sedimentation. The two case study areas are largely composed of so-called Intermediate Zones - marginal areas with fluctuating settlement, although they contain elements of both Zones of Attrition and Zones of Preservation. However, as evidenced by the extensive list of examples throughout this chapter, damage is occurring to sites across the survey areas.

More than thirty years ago, Adams commented:

> *"A reduced rate of site recovery is unavoidable throughout the upper part of the plain because of relatively widespread and intensive agriculture, large-scale land levelling and drainage projects , road construction and many other forms of disturbance associated with the modern development of the Iraqi economy" (1981: 209).*

Despite the passage of time, this study is the first to attempt to quantify those disturbances in the Near East, and to try and find a way to monitor them, and evaluate their impact on site recovery.

There are obviously caveats. It is clear that damage to sites occurs from a variety of sources, not all of which are visible on satellite imagery. It should also be noted that only threats that relate to sites in the Middle East have been covered in any detail. Also excluded were threats to off-site features. Some are extremely difficult to detect on satellite imagery, such as the wine press shown in Figure 3-49. Others, such as hollow ways, were excluded due to the constraints of time and space – it was decided to limit the extent of the study to 'sites' rather than features (whilst acknowledging the problematic complexities of the terms). The damage caused to inundated sites was also excluded, even though both case study areas are by large dams, and some sites may or have been inundated. Inundation processes are poorly understood and appear to be extremely context specific. A major study was carried out by Lenihan (1981), but it was specific to sites in North American reservoirs: he commented that each reservoir situation was unique. This work is currently being updated by Stammitti at Edinburgh University, but the results have not yet been published. Other omitted threats include c-transforms such as alterations to standing buildings, as these can only be detected by site visits. The reconstruction and restoration work at Tell Beydar is not treated as damage, although it is an alteration to standing architecture, as such work is necessary for the preservation of mudbrick architecture. Without it, it would simply wash away. Extremely small threats that cannot be seen on imagery and are rarely noted during field visits are also excluded, such as the animal burrowing at LCP 53 which was deep enough to provide "*a good window into earlier deposits*" (field notes 2009).

The damage discussed here has severe effects, not all of which are obvious. Many threats alter site form and extent. The field report of bulldozing damage at TBS 59 (Figure 3-36) showed that the altered form of the site was not discernible. The survey team were informed by a local farmer that the mound was no longer in its original form. They had not realised this during the survey of the site, highlighting the problem. Site damage not only causes inevitable loss of the resource and the accompanying loss of knowledge, but unless its occurrence is taken account of, further mistakes can be included in archaeological work. Many settlement studies in this region, for example, are based on estimates of site size as proxies for population density. If the estimated site size is wrong, because the site has since been altered, then the proxy population data will be wrong.

The true significance of the damage, however, can only be determined through comparative study of the sites in question, placing them in their wider regional framework (after Darvill et al. 1987). By examining, recording and analysing damage to archaeological sites on sequential satellite imagery, the effects on sites will be quantified for the first time. The following chapter will discuss how this can be accomplished in the selected case study areas. As demonstrated, there are many complicating factors in how damage affects sites and how it appears on imagery. However, it is not enough to record damage to sites: it must be analysed to determine the most severe effects so that protection policies can take account of the threats. This will also provide a benchmark against which future damage can be assessed. The factors affecting how sites appear on imagery, the methods developed to deal with them, the design and creation of a database for recording the damage, and methods of analysing the records are discussed in the Methodology Chapter 4.

"The most important fact of this century is not that Earth is threatened in many ways, it is that for the first time in all of its history a decisive means of protecting the home planet exists. It is by using space."

~ William E. Burrows, The Survival Imperative (2006) ~

Chapter 4:
Methodology and Conventions

4.1 - INTRODUCTION

This research project seeks to develop methods of utilising satellite imagery in conjunction with data collected during field surveys by the Fragile Crescent Project (Chapter 2.3 – the Fragile Crescent Project) to collect new data in order to assess damage to archaeological sites in the Near East. Discussions of damage to sites, particularly in the Near East, have been largely (although not entirely) anecdotal, necessitating the development of a new methodology.

An assessment of damage involves several steps which will be discussed in order. The first is site identification (site definition is discussed in Chapter 2.2 – the Nature of the Archaeological Resource, p10). The second is to monitor changes in the site over time; third is recording of the damage. Once the data has been collected, new methods of analysis have also been applied to the data, in order to quantitatively analyse site damage on a regional scale for the first time.

Traditional methods of survey, for example ground reconnaissance methods such as driving from site to site, or field-walking, are vital to understanding the landscape. However, they are limited in that they are time-consuming and therefore costly. Furthermore, in order to monitor change, these site visits would need to be repeated on a regular basis. Remote sensing offers the opportunity to monitor large numbers of sites in a quick and more cost-effective manner. This is not to suggest that ground verification can be dispensed with. Remotely sensed data can only be fully understood in relation to ground control or survey data (and sometimes not even then), but multiple ground visits may not be necessary. Using verified data it may then be possible to determine regional trends, or patterns which are applicable to areas with similar characteristics. The landscape survey techniques employed in the two case studies provide the foundation for this study, which is intended to demonstrate the potential of satellite imagery in cultural resource assessment, specifically site monitoring and damage assessment.

4.2 – Background to Monitoring Site Damage

The methodology and framework utilised here builds on the methods developed for the England-based Monuments at Risk Survey (Darvill and Fulton 1998). This survey, also known as the MARS survey, developed a framework to, amongst other things,

> *"collate information on the condition of these monuments so that the resource requirements for future preservation, and the priorities for action, can be assessed ... on a systematic and nation-wide basis"*
> (Darvill et al. 1987: 393).

As discussed in Chapter 3.4.1 – the Significance of Damage, the MARS survey also attempted to build site importance and rarity into their damage criteria (Darvill et al. 1987: 396). Whilst these criteria unarguably added depth to the study, many involved comparisons of monument classes on regional or national scales to determine representivity, requiring a great deal of cross-comparison with other sites – it took Darvill and his team years to collect and standardise comparative data on a national scale, and it is not available anywhere else. The wider application of these criteria requires more information about each site than was available for the sites in Syria: numerous site visits, and potentially excavation, may have been required to collect it. Given the lack of excavation of many of the sites in the selected survey areas, and lack of intensive survey elsewhere, criteria such as their relative rarity, for example, can only be estimated.

Damage extent in the MARS survey was calculated using the percentage area loss of sites over time. The assessment was based on a combination of information sources, including the Sites and Monuments Record (SMR), which detailed the site type and materials, the known condition of the site and site visits to determine the actual extent as compared to the record. Various criteria were also developed to try and minimise observational bias by the different people conducting the study. However, as discussed in Chapter 2.2 – Site Extents, the site extents determined in the field are not always correct, and even if they are it is very difficult to determine accurate site extents on satellite imagery. There are no SMRs available in Syria - in many cases the survey notes constitute the only available record. As will be discussed further in Section 4.5.5 – Recording Change: Type and Extent of Damage, an accurate quantified numerical examination of change in site extent from satellite images is impossible at this time.

It was not for some years that an attempt to monitor damage would be conducted in the Near East. In the wake of the wars in Iraq in 1990 and 2003, reports indicated that looting was spiralling to previously unheard of proportions. A team of archaeologists went to conduct a limited but vital damage assessment of the major sites (Wright et al. 2003). The total area looted just after the 2003 war was estimated to be greater than all the archaeological investigations ever conducted in southern Iraq (Stone 2008). Ground conditions prevented visits to all the sites to assess the extent of the problem, so in 2004, Van Ess *et al.* (2006) successfully used IKONOS to assess the looting and site damage at Uruk. Two years later Stone trialled a remote-sensing based method to examine the scale of looting at multiple sites (2008). Data was collected on over 1,900 sites to assess which were most likely to be in danger from looting: a limited number of those sites were examined on Digital Globe imagery acquired immediately before or shortly after the war. Attempting to account for differing conditions between images, nearly 10,000km^2 of imagery was examined. Criteria for evaluating looting based on the density and distribution of the holes, and on visual traces, such as the sharpness of the edges and apparent size of the holes, were developed. The site circumference was estimated from the imagery, rather than site records, then digitised, and this was used to estimate the area damaged. Assessments were then made of the extent of the looted area, the targeted periods, and the intensity of looting as relating to size of site. Whilst an extremely interesting study, Stone reportedly no longer supports all of her conclusions (John Curtis, British Museum, *pers. comm.* 2009). Later field visits apparently showed the criteria by which she evaluated the looters' holes did not accurately reflect the state of the sites on the ground. Another study was later conducted by Lasaponara and Masini (2010), using spatial autocorrelation statistics and remote sensing to monitor looting in Peru. Although an interesting attempt, this study was also not detailed enough to be more widely applicable.

The first study attempting to use remote sensing as an on-going method of site monitoring was carried out by Parcak, who monitored large tells in Egypt (2007). Her method focused primarily on identification, and discussed the different problems in the different areas of Egypt, comparing the Delta and Middle Egypt. However she notes:

> *"Sites and their satellite data can be monitored from computers anywhere in the world, but it must be stressed that only gross*

landscape and settlement changes can be followed with lower-resolution satellite imagery … Such monitoring can assist with site protection, preservation, and liaising with government officials. Physical changes over time, such as site destruction and looting, can be tracked with Quickbird satellite images … At present there is no economically feasible solution for those who wish to obtain Quickbird on a regional scale" (Parcak 2007: 76).

Nonetheless, even using older Corona, or lower resolution modern imagery such as SPOT (backed up with field visits and local interviews), impressive regional results were obtained. In one area alone, 23% of ancient sites disappeared over a 30 year period, with 76% undergoing full to partial removal. Less than 20% were free from obstruction by buildings. 8% of sites studied were below modern towns. However, as discussed in the Development Section in Chapter 3.7.1, the presence of a town does not always equate with complete destruction. Whilst an extremely important study, it was limited by the economic viability of obtaining high enough resolution imagery, and the results were supported by extensive field survey, which may not always be possible. As a result, the study was limited to larger sites, rather than small sites, or landscape features, which also comprise a significant part of the archaeological record. The treatment of the damage to tells was also simplistic, necessitated again by the low resolution.

Work in this area is continuing, taking advantage of the higher resolution imagery as it becomes available, but it is often qualitative, and focused on the recovery of past landscapes, rather than on assessing their remains. Casana *et al.* (2012), for example, have recently published an exploration of general damage experienced by sites across the Middle East, using comparative imagery to illustrate threats including development. They note

> *"As the city [Mosul] has grown rapidly in recent decades, it has come to cover increasing portions of the ancient city of Nineveh. New developments on the long-protected northern part of the archaeological site suggest that this ancient city may soon be nearly completed [sic] obscured by modern development"* (Casana et al. 2012).

Whilst identifying high risk threats to important sites is an excellent use of sequential imagery, there is a lack of context to this comment. No details are included about Nineveh, such as the extent or depth of the site which might be affected, or what will happen if the site is "completely obscured", other than a lack of visibility on imagery?

Those investigations represent the major studies into the identification of site damage, and based on their successes and pitfalls, the following methodology was developed for regional–scale use. This methodology has the major advantage over its predecessors that, thanks to Google, high resolution imagery is becoming freely available, which allows much more detailed regional studies, and more advanced analysis.

4.3 – Remote Sensing – History and Value

It is not the intention here to define remote sensing and how it works in any detail, either generally or when specifically applied to landscape archaeology in the Near East. These topics have been well covered elsewhere (for example see Beck 2004; Beck et al. 2007; Galiatsatos 2004; Kouchoukos 2001; Lillesand et al. 2008; Parcak 2009; Sabins 1996; Wilkinson et al. 2006).

Although remote sensing is used primarily to support surveys, articles like these also demonstrate that the benefits in damage assessment are clear. Large numbers of sites can be monitored without the need for expensive and time consuming site visits, and if suitable imagery can be obtained, change over time can be monitored. However, the caveats of such an approach are also clear: the 'top-down' view of the world provided by imagery can be hard to interpret, and numerous factors can affect its interpretation. A large body of literature has been developed on the interpretation of satellite imagery which has also informed this methodology.

Viewing sites in the Near East (or elsewhere) from the air is not a new approach (for a detailed history of the earliest aerial photography see Kennedy 2012). Growing out of the need for information in World War 1, aviators were flying and co-incidentally (then deliberately) photographing sites by 1915. The most well-known of these early military archaeological aviators was Poidebard who photographed (and sometimes recorded) large parts of the Syrian landscape between 1925-1934 (for example Poidebard 1930; 1934; Poidebard 1938; Poidebard et al. 2004; Poidebard and Mouterde 1939; Poidebard et al. 2000). Other major programmes were conducted by Stein and by O.G.S. Crawford (Crawford 1924; 1929a; b; Kennedy 1982). After WWII such work was disrupted and never resumed on the same scale, although some archaeologists managed to obtain access: van Liére and Lauffray (1954) worked in the Syrian Jazirah, Adams (1981) in Iraq, and Villeneuve in the Syrian Hauran (1985), and later Kennedy conducted extensive aerial surveys across the Near East (Kennedy 1998a; Kennedy and Bewley 2008; 2009; Kennedy 1982; 1998b; 2012; Kennedy and Riley 1990). It is only now with the recent availability of affordable high resolution imagery that such large scale studies are once again becoming possible. Many of these studies, although focussing on settlement patterning, have noted the effects of anthropogenic landscape change on their study. For example Hritz, in her reconstruction of Mesopotamian channels and settlements, noted “despite centuries of on-the-ground archaeological investigation, the impact of long-term human modification of this ancient landscape remains an obstacle” (Hritz 2010: 184). However, such comments have remained largely un-quantified.

The Fragile Crescent Project (detailed in Chapter 2.3) seeks to utilise a variety of remote sensing data to supplement the field survey records and integrate them using a computer Geographic Information System, or GIS, an approach which is slowly starting to become more common (for example Pournelle 2007; Stone 2008; Ur 2003). Field data has been collected using a variety of methodologies, with imagery utilised to different extents. Imagery comes in a variety of forms with a range of enhancements available: interpreting imagery data is also inherently subjective. From c. 1999, Corona was sometimes utilised to aid site prospection and understanding of the landscape. It was also used to re-examine older FCP surveys, providing additional context and information about the known sites, and guidance on what archaeological sites may look like in those areas to aid the discovery of possible new sites (Lawrence 2012: 66). During the surveys, both recent high resolution imagery and older Corona imagery were obtained where possible, showing the landscape at the advent of industrialisation (in the late 1960s) and compared to the modern day. Some surveys, such as the Tell Beydar survey, were conducted before high resolution imagery was commonly available, although SPOT imagery from the mid-late 1990s was utilised. In the LCP survey, Corona, 2003 DigitalGlobe imagery and 2009 panchromatic Geoeye were all examined. This approach is utilised in this study.

As pointed out by Kennedy (1998a), Philip *et al.* (2002), Hritz (2010; 2013; Hritz and Wilkinson 2006) and Casana et al. (2012), amongst others, Corona imagery offers the potential for new and valuable discoveries in the Near East. Sites and features can be identified or even discovered, and interpreted in the context of the landscape that would have created and / or supported them. Relict paleochannels of rivers can become visible, and old wadis traced, elucidating the water needs of the ancient populations, as well as ancient field systems and burial monuments such as cairns. These pioneering articles also highlighted the value of the imagery for landscape change detection, and the potential for monitoring site damage:

"CORONA is likely to prove of great value to local antiquities organizations in regions where rapid population growth and economic development are placing great pressure on an inadequately documented archaeological record.

Ground observation has revealed that extensive areas of the landscape described above have been destroyed in recent years … CORONA preserves evidence of the landscape as it was" (Philip et al. 2002: 115).

However, Corona does have its limitations (Beck et al. 2007). Due to the inherent high distortions, the georectification process is not always accurate. Features visible from the aerial perspective of Corona are not always visible on the ground, exacerbated by the panchromatic nature of Corona, the density of landscape features, and the degree of landscape modification which make some areas (and thus sites) almost unrecognisable. Corona is also ineffective at recognising small or sparse artefact scatters (Philip et al. 2002). Features between 1-3m in size have been identified on high resolution panchromatic imagery in Norway (Grøn et al. 2011), and verified on the ground: however the cost of purchasing such imagery has remained prohibitive.

Recently, a large amount of very high resolution imagery has become available through Google Earth, and it was chosen as the comparator to Corona for several reasons. Whilst there was no control over seasonality, or the other factors which affect spectral signatures, and it is not all high resolution (<2m), it is free and requires very little technical knowledge and no expensive specialist software to utilise. This means that if it is shown to be suitable in spite of the issues, it can be utilised by cultural heritage managers, who often operate on a tight budget. Google have also stated that they intend to regularly update their imagery, allowing a degree of monitoring as long as suitable methods can be developed. Details of all the imagery chosen for use in this study is detailed in Table 4-1. Details of the image processing methods used are in Appendix A. All images are interpreted using the field survey data as a benchmark, and change is assessed around that. [65]

[65] In July 2012 Geoeye and DigitalGlobe merged.
DigitalGlobe News Room. 2012. Digitalglobe and Geoeye Agree to Combine to Create a Global Leader in Earth Imagery and Geospatial Analysis. *DigitalGlobe News Room* [Online]. Available: http://media.digitalglobe.com/press-releases/digitalglobe-and-geoeye-agree-to-combine-to-create-nyse-dgi-0911703 [Accessed 25 December 2012].

In this thesis, DigitalGlobe refers to the imagery that was available from that company on Google Earth pre-2012, and is distinct from Geoeye imagery, which was separately owned at the time. Google Earth do not specify whether they are hosting DigitalGlobe's WorldView imagery or their Quickbird Imagery.

TABLE 4-1: DETAILS OF IMAGERY USED IN THE STUDY[66] [67]

Imagery	Frames	Source	Resolution (M)[68]	Dates (Launch / acquisition)	Spectral Properties	Strengths (Corona taken from Ur, 2010a)	Weaknesses (Corona taken from Ur, 2010a)	Coverage
Corona 1021-2120D	008	USGS (FCP)	4m	18.05.1965 / 26.05.1965	Panchromatic	Moist and vegetated ground at time of acquisition; good for hollow ways and depressed features	Lower resolution than later missions (KH-4A camera)	Tell Beydar
Corona 1038-2120D	063, 064, 065, 066, 067, 068	USGS (FCP)	3m	14.01.1967 / 22.01.1967	Panchromatic	Fair image quality for a KH-4A camera	Lower resolution than later missions (KH-4A camera)	LCP
Corona 1102-1025D	006, 007	(Ur, 2010a) USGS (FCP)	2m 4m	09.12.1967 / 11.12.1967	Panchromatic	Sites and hollow ways more visible. Area near nadir, optimal resolution, least distortion	-	Tell Beydar
Corona 1104-1009D	011, 012, 013, 014	USGS (FCP)	2m	07.08.1968 / 08.08.1968	Panchromatic	Some of the best imagery on any KH-4 systems	Image quality is very poor in the LCP area	LCP
Corona 1105-1025D	056, 057, 058	USGS (FCP)	4m	03.11.1968 / 05.11.1968	Panchromatic	Tracks, field boundaries and built structures; highest resolution camera	Acquired in dry season – too dry for hollow way visibility	Tell Beydar

[66] Where only one resolution is given for Corona, it is the average resolution for the relevant sections of the frame, as it can vary.
[67] FCP-supplied Corona imagery was georectified by Dr Galiatsatos. He also corrected the 2009 Geoeye (See Appendix A).
[68] Where only one resolution is given for Corona, it is the average resolution for the relevant sections of the frame, as it can vary.

Imagery	Frames	Source	Resolution (M)[68]	Dates (Launch / acquisition)	Spectral Properties	Strengths (Corona taken from Ur, 2010a)	Weaknesses (Corona taken from Ur, 2010a)	Coverage
Corona 1117-1025D	148, 149	(Ur, 2010a)	2m	25.05.1972 / 25.05.1972	Panchromatic	Hollow ways, wadis, natural drainage	Site sediments are saturated, often indistinguishable from surrounding fields	Tell Beydar
DigitalGlobe imagery	1010010001EF5003	Google Earth	0.5 x 0.6m	27.05.2003	RGB Composite			LCP
DigitalGlobe imagery	10100100023FAD03	Google Earth	0.5 x 0.6m	02.09.2003	RGB Composite			LCP
SPOT 2004 imagery	Unknown	Google Earth	2.5m	SEE Appendix A, 1.1	RGB Composite		Probably taken in summer so lower visibility	Tell Beydar LCP
DigitalGlobe imagery	10100100081B8A09	Google Earth	0.5 x 0.6m	01.06.2008	RGB Composite			LCP
Geoeye imagery	Unknown	Google Earth	0.5m	26.07.2009	Pan-sharpened			LCP
Geoeye imagery	Unknown	Google Earth	0.5m	22.09.2009	Pan-sharpened			LCP
Geoeye imagery	002 - One image	FCP	0.5m	26.07.2010	Panchromatic			LCP
Geoeye imagery	000 - Mosaic of 3 images	FCP	0.5m	22.09.2010	Panchromatic			LCP
Geoeye imagery	001 - Mosaic of 2 images	FCP	0.5m	10.11.2010	Panchromatic			LCP
Geoeye	002 - One image	FCP	0.5m	26.07.2010	Multispectral			LCP

Imagery	**Frames**	**Source**	**Resolution (M)**[68]	**Dates (Launch / acquisition)**	**Spectral Properties**	**Strengths (Corona taken from Ur, 2010a)**	**Weaknesses (Corona taken from Ur, 2010a)**	**Coverage**
imagery								
Geoeye imagery	000 - Mosaic of 3 images	FCP	0.5m	22.09.2010	Multispectral			LCP
Geoeye imagery	001 - Mosaic of 2 images	FCP	0.5m	10.11.2010	Multispectral			LCP
Geoeye imagery	Unknown	Google Earth	0.5m	23.06.2010	RGB Composite	Crops just planted, ploughlines, cropmarks relict wadis and hollow ways quite visible	Soil marks not visible	Tell Beydar
Geoeye imagery	Unknown	Google Earth	0.5m	17.08.2010	RGB Composite	Highest resolution	Imagery is pinkish. Fields are bare, sites do not show up as well, nor do routes or hollow ways	Tell Beydar
Geoeye imagery	Unknown	Google Earth	0.5m	22.10.2010	RGB Composite	Highest resolution	Imagery is pinkish. Fields are bare, sites not as clear	Tell Beydar
Landsat TM imagery	p171r034_5dt19900529_z37 p171r035_5dt19900529_z37 p172r034_4dt19900528_z37 p172r035_4dt19900901_z37	www.Landsat.org	30m	1987-1990	Multipsectral. (Although Landsat TM has 7 bands, band 6 was not available for this study)	Multispectral. Imagery pre-dates the building of the West Hassake dam, the more recent drought, and ensuing intensification of irrigation	Low resolution	Tell Beydar (other areas available but not tested)

Initially the feasibility of using multispectral imagery, as well as panchromatic, colour and pan-sharpened imagery was considered. Multi-spectral Aster and IKONOS imagery have been found to be useful for site identification in the Near East (Agapiou et al. 2012; Altaweel 2005; Beck 2004; Beck et al. 2007; Menze and Ur 2007; Menze and Ur 2012) but the cost of high resolution imagery for regional studies is often prohibitive. Other methods were developed to enhance crop-mark detection in multi-spectral imagery (Aqdus et al. 2012), but the resolution proved inadequate, and higher resolution imagery was too expensive. Furthermore, few sites in the Middle East form crop-marks as would be seen in the areas studied by Aqdus et al. Sites in the Tell Beydar area were examined in a trial run using a mosaic of multispectral Landsat imagery from between 1987-1990 (30m resolution). This was some of the earliest Landsat Thematic Mapper imagery available, and it was hoped that sites (if visible) would be less degraded. Landsat imagery was examined using a variety of band combinations to try and highlight different components of the spectral signature of sites (detailed in Section 4.4). A Normalized Difference Vegetation Index was created, and Principal Component Analysis was also run to try and highlight features.

Unfortunately, the resolution of the Landsat imagery was too low to see most of the sites in the Beydar area, which were often small, and many of the larger sites are obscured by modern villages, and cannot be distinguished from their covering. The sites which could be discerned seemed arbitrary, and no consistent results could be obtained.

The uses of satellite imagery for archaeological prospection are well documented (Altaweel 2005; Aqdus et al. 2012; Beck 2004: 231; Beck et al. 2007: 509; Donoghue 2001; Menze and Ur 2012; Philip et al. 2002: 112), and during imagery analysis, previously undetected spectral signatures which may well be sites or additional features are sometimes visible. As the existence and nature of these features have not been verified through ground survey they have been excluded from analysis.

4.4 – Identification of Sites on Satellite Imagery

A number of digital techniques have been developed for identification and classification of visual features (both archaeological and others), with varying degrees of success. The present research seeks to go beyond the identification of archaeological sites, intending to utilise imagery to study them. Digital classification currently indicates only the potential presence / absence of sites, therefore the techniques used in this project rely on visual interpretation. There are three key markers – elevation (i.e. identifying the shadow cast by high sites), distinct features (i.e. morphological or structural elements observable on imagery), and spectral reflectance (after Beck et al. 2007; Hritz 2013: 1979, but also; Ur 2003; Wilkinson 2003). However, correct interpretation requires an understanding of the factors influencing what we see on imagery, and why it appears as it does.

The key to interpretation in remotely sensed imagery is the spectral signature of the archaeological site or feature. A spectral signature is the unique spectral response that a feature displays over a range of wavelengths on the electromagnetic spectrum, in this case as it is captured by a sensor and appears on the imagery produced (Lillesand et al. 2008; Sabins 1996). For the reasons discussed, this study utilises RGB imagery, rather than multi-spectral imagery, and therefore this section will discuss only those spectral signatures from the visible portion of the electromagnetic spectrum.

The causes of the spectral signature of an archaeological site or feature are not fully understood, and there is no single spectral signature that is characteristic of archaeological residues (Beck 2004). In some ways the visual appearance of a site on satellite imagery is similar to its appearance on aerial photography, where crop marks, soil marks, parch marks or shadow sites may show up, each one formed by different cultural and natural processes, and visible only in specific environmental conditions. In particular, the appearance of sites is interpreted visually through the contrast of the site against its background, either directly (the site itself is visible), or indirectly (such as through crop marks) (Beck 2007).

However, the interpretation of satellite imagery evidence is slightly more complicated. Increased atmospheric particulates in the spring and summer vastly reduce image quality (Donoghue et al. 2002). Vegetation and deposited silt can mask the spectral signatures of sites (Beck 2004). Furthermore, features such as walls and ditches create different surface evidence in the Near East compared to Europe. European theories of aerial image mark formation are therefore not always applicable. Due to increased levels of moisture retention in decomposing mud-brick, many sites are more-easily identifiable by the ensuing increased vegetation (Kouchoukos 2001), hence a Normalised Difference Vegetation Index is sometimes suggested as a useful tool for multi-spectral imagery: it enhances the vegetation which might indicate a site. Work by Wilkinson *et al*. (2013: 57) around the Gorgan Wall has demonstrated that differential salinization can also be used to detect sites and features, such as relict field boundaries.

This was also noted by Elizabeth Stone (*pers. comm.* 2012) on walls in southern Mesopotamia, especially after episodes of rain followed by drying.

Soil samples taken by Beck in Homs (2004; Wilkinson et al. 2006) were analysed to try and ascertain what factors of soil composition led to sites appearing on Corona imagery. Some of the sites sampled were visible as pale patches of higher reflectance, and some of darker, lower absorbance. The samples were compared to a Munsell colour chart (Munsell Color Company 1975) which demonstrated that the colour difference between wet and dry off-site soils is very small, but that there is a large difference between wet and dry on-site soils. Furthermore the on-site wet colour is very close to both the wet and dry off-site soil colour. From this it was deduced that the drier the soil, the greater the colour difference of the soil on and off the site, and the easier it is to determine archaeological residues. It should therefore be easier to see sites in drier weather. The driest season in Syria is May / June to September. Autumn rains begin in September and continue through to the following April / May, allowing a winter crop to be grown. During this period the soil is moister, the water table rises, and areas which hold standing water appear darker.

The imagery selection process for Corona in Homs (Beck 2004) determined that, for crop avoidance, the months of September to October are best for image acquisition. Imagery collected between February and May would have the lowest likelihood of detecting archaeological residues as the increased moisture reduces the colour differences between soils on and off sites. However, the drier the weather, the more the image is affected by atmospheric distortions and haze, and sites which are composed of field scatters may be less visible as dust covers the scatter, impairing visibility.

The data from Homs provides the closest analogy for Carchemish or the Jazirah, and work was done in Carchemish which validated the soil appearance results (Section 4.6 – Fieldwork and Verification). The Corona data used in the Jazirah study was acquired in May, November and December. However, as mentioned, coverage was not even. 49 of the 83 sites were covered by May imagery, 60 by November imagery, and 73 by December imagery. No imagery was acquired in the most arid season. However, as can be expected, the differential acquisition dates highlight different features. Ploughing, for example, is particularly visible on the 1105 imagery (November), but not on the 1102 (December) imagery, when crops are starting to grow, or the 1021 (May) imagery when crops are clearly well advanced and the fields appear dark. Many of the sites also appear to be more visible on the November and December imagery, compared to the May imagery. Only one site (TBS 54) is covered by 1021 Corona.

The Corona data for the area around Carchemish was acquired in January and August, and both sets cover all the sites. Although August imagery should be clearer, very little detail is actually visible. The increased moisture levels in the January image seem to have enhanced the clarity of the sites and associated features.

The theory of reflectance and spectral signatures, and the visibility and interpretation of sites on imagery is extremely relevant to the interpretation of archaeological features on Corona. However, on later imagery the spectral signatures of sites are less visible due to changes in land use. For example, increasingly widespread irrigation has enabled the extension of the cropping cycle: some areas are under nearly continuous crop cover, masking the spectral signature of the sites. This is particularly problematic on SPOT imagery which, despite the date given on Google Earth, was probably taken during the height of summer when crops and dust cover the ground.

The Geoeye imagery around Tell Beydar was taken in July, August and October. August and October are clearly between crop cycles, as many fields are bare and soil marks are more visible. Many empty fields are also visible in the July imagery - plough lines are clear, as are many cotton fields (supposedly a winter crop). The Geoeye and DigitalGlobe imagery for Carchemish were taken in September: again many fields are empty and freshly ploughed and sites are more likely to be visible. Given the high resolution of the panchromatic Geoeye imagery (0.5m), image clarity is higher, and the ensuing interpretation relies less on an understanding of spectral reflectance than the interpretation of earlier imagery. However, even on high resolution images crop cover can still hinder interpretation of archaeological sites and features. Figure C-1 (p491) shows LCP 51 under crop cover on DigitalGlobe imagery; the site is clearer when not covered by crops, for example on the June Geoeye imagery (Figure C-2).

Different environmental zones produce different archaeological signatures, as people used the land in different ways, but some areas can also mask such signatures. For example, few tell sites are visible on the limestone bluffs in the area south of Carchemish, as there is very little tell-based occupation in the area. Where tells are visible, they are relatively obvious. The non-tell sites are particularly hard to see on imagery (and on the ground), as the reflectance of the limestone outcrops is similar to archaeological site residues. Equally, sites along the Euphrates River terraces may have been masked by overlain alluviation or deposits from alluvial-colluvial fans.

Multiple soil types and varied geology cause variations in the appearance of archaeological residues. These areas have also been subjected to millennia of changing land uses. These past uses will have differentially affected the sites, and later land-use practices, such as stone robbing and ploughing will also have affected them, giving sites a potentially unique appearance.

In some areas of Syria, higher quality agricultural soil has been removed from one area and re-deposited elsewhere, burying the original surface: this masks any archaeological residues which were present (Beck 2004: 319). The water table has also dropped in many areas, and irrigation, and therefore vegetation, is increasing. Over time irrigation will increase the salinity of the soil, and moisture levels will not be comparable to those visible on Corona. Recently, however, the drought in Syria has caused many farmers to abandon the Jazirah and move to towns in search of work as the farms become unsustainable (Trigo et al. 2010). It is unclear what the effect of the combination of these factors is, as numerous changes have occurred in a short space of time, and cannot be 'unpacked'.

Ur (2003) recognised that anthropogenic modification of soils at archaeological sites led to changes in their reflectance, and that it is linked to the moisture content of the soil. In particular the decomposing mudbrick mixes with anthropogenic ash (and other refuse), and is slowly incorporated into the soil matrix, where it continues to develop into increasingly less distinct soil horizons, until it is indistinguishable from the original soil horizon. It was estimated in the North Jazirah that this process took approximately 7,000 years, and that only the most resistant artefacts remained (Wilkinson and Tucker 1995: 6). The visibility of archaeological sites therefore also reflects the interaction between the surface characteristics of the site, the soil and the vegetation, and the subsurface characteristics.

In some cases, site types are distinctive enough that they may even be (tentatively) dated. For example, in the eastern Jazirah, in Iraq, Sasanian and Islamic sites typically appear as low, often irregular, sprawling mounds with conspicuous grey soil colouration and many enclosed hollows. These show up as dark areas, particularly on Middle – Late Islamic sites (Wilkinson and Tucker 1995: 69), whilst high tells in the Jazirah are all Early Bronze Age with occasional later occupation (Wilkinson 2003).

Clearly there are multiple factors which influence the appearance and identification of archaeological sites on imagery, hence the recommendation to use images which are from the same approximate seasons, in order to limit the inconsistencies which affect interpretation. However, this is not cost-effective, and is less important on higher resolution imagery: this will be discussed further in Section 4.5.1. Furthermore, the aim of the current research is not to identify sites, but to assess and monitor damage to them using cheap and freely available imagery. Whilst it is vital to understand how and why sites appear as they do in order to evaluate the effectiveness of the methods used to assess damage, this is the not the goal.

In order to recognise damage to archaeological sites, the land cover and land use must be identified to judge the effect. In some cases, it may not be possible to see the site at all, but if the site location is confirmed and the land cover can be identified, damage can be estimated. If features can be identified, the primary issue then becomes how much of the feature can be identified, and what condition it is in (and with what level of certainty). It should be stressed however, that the goal here is not the interpretation of site features, but the detection of damage. The importance of identifying land use, land cover and damage, and the methods used to do this, are discussed in more detail in the following sections, and examples are given in Appendix B.

4.5 - RECORDING CHANGE

4.5.1 – USING IMAGERY TO MONITOR CHANGE

In order to monitor damage to archaeological sites, change over time must be assessed. Satellite imagery provides an excellent platform from which to undertake this, as it is quicker and more cost effective than site visits. Comparing sites and features on multiple images, an approach discussed in Section 4.4, often enables easier identification and interpretation. However, the more information that is available, such as from field notes taken during ground survey, the clearer the interpretation - results become much less prone to error.

When considering the uses of satellite imagery for cultural resource management, Beck (2004) discussed change detection on archaeological sites and considered the factors which affect it (discussed in Section 4.4). These can lead to different reflectance levels and therefore the different appearance of sites at different times of year. Beck's suggestion to minimise these effects is to use imagery with similar resolutions, collected at similar times of day in similar months. Unfortunately, the costs of this can be prohibitive for many organisations that do not have the resources for bespoke imagery orders.

An alternative solution is simply to use as many images as possible, taken at different times of year, thereby widening the range of perspectives. In order to compare how damage to sites changes over time, an 'average' site appearance is needed for each time period, for example a condition assessment for a site in the 1960s would be derived from all available Corona images. This will give a picture of the site which is informed by multiple images, thus low resolution, moisture levels, sun angle, and so on, will all be taken into account to provide the most detailed information possible. For example, as discussed in Section 4.4, the use of multiple Corona images from different seasons assisted the identification of archaeological features as the different reflectance profiles were highlighted. Whilst this is more time-consuming, the results will be more detailed, more accurate, and more robust, and this is the approach which has been adopted here.

One of the goals of this study is to evaluate the potential of cheap imagery sources, like Corona, or free sources, like Google Earth. Whilst many Corona mission images are of good quality, they were not taken with archaeological site detection in mind, and therefore are from a variety of seasons and times of day. Equally, the imagery available on Google Earth is also from a variety of dates, which will not necessarily produce comparable spectral signatures.

It should be noted that this approach prohibits automation of the methodology. Automated change detection would be extremely useful - it would speed up data collection, and enable wider implementation of the methodology, but in this case it is not appropriate (see Campbell and Wynne 2011 for overview and detailed bibliography). Firstly, the imagery taken is, as discussed, from a variety of seasons. Many changes detected via automation could potentially be seasonal differences, rather than actual change. This is easier to assess manually. Secondly, data used through Google Earth cannot be automatically assessed: utilising data outside Google Earth would drastically increase the costs, rendering this analysis of change monitoring useless for organisations with small budgets. Thirdly, automated change detection is, at present, still far more successful on larger sites such as substantial tells. One of the big advantages of this study, and in fact one of its main goals, is to assess damage on all sites in an area, large, small, tall or flat. Whilst a manual assessment of change is far more time-consuming, it will produce one of the most comprehensive studies of damage to the entire archaeological resource in any area with no sites excluded. Archaeologists must not exclude smaller sites simply for convenience (although it is acknowledged that faster methods of change detection can cover larger areas, which is an alternative benefit).

4.5.2 - Database Structure and Fields

A specially designed Access database (included on the attached CD – Appendix I) has been used to record all the data relating to damage on each site in the case study areas. Some of the fields and terminology are based on those used in the FCP database, which in turn is based upon the Homs / Vanishing Landscapes database. All the databases use the same ID system for the sites. The site ID, called the Major ID field, is used as the primary index key, allowing data to be cross-referenced between the different databases. Carchemish, for example, is identified by the survey moniker "LCP" and the site number – 46. This is the level 1 ID. The site is composed of two parts: the tell – part "1", and the outer town –part "2". These are the level 2 IDs. If further work was done, for example, trial excavations within a particular area, these would be identified with a level 3 ID. As the goal of this research was to look at site sections, rather than small features, few areas identified by a level three ID have been included. The entire site of Carchemish, therefore, is identified as LCP_46_0_0. The tell and outer town are LCP_46_1_0, and LCP_46_2_0, respectively. In the FCP database, records created for a series of transects in the outer town are identified by level 3 IDs: these were not included in the site damage database.

Within the database, a record is created for each sub-part of a site (henceforth called a site unit), and an amalgamated record for similar parts of each site (defined in Section 4.8.1 – Analysis by Site Type). (See Figure 4-1 for a screen capture of the Site Information tab from the database.) For each site the ID, sub-IDs, survey ID and name are recorded, as well as the site type, the aspect of the site, its location, the record author, and the field observer and observation year. Numerous details are recorded in check-boxes, enabling complex queries to be run.

Aspects relating to the site which were recorded during the field visit are noted on a Site Information sub-record: the dimensions, height, presence of subsurface remains or architectural features, visible soil marks, pottery scatters, whether the site unit is part of a complex of low mounds (or the site contains a complex of low mounds), whether the mound is topographically complex (i.e. has multiple peaks), and whether the field visit recorded the site as an 'outer town' or 'lower town'. Outer towns can have different site attributes depending on their location, so here a site is only described as an outer town if that appellation was prescribed in the field visit.

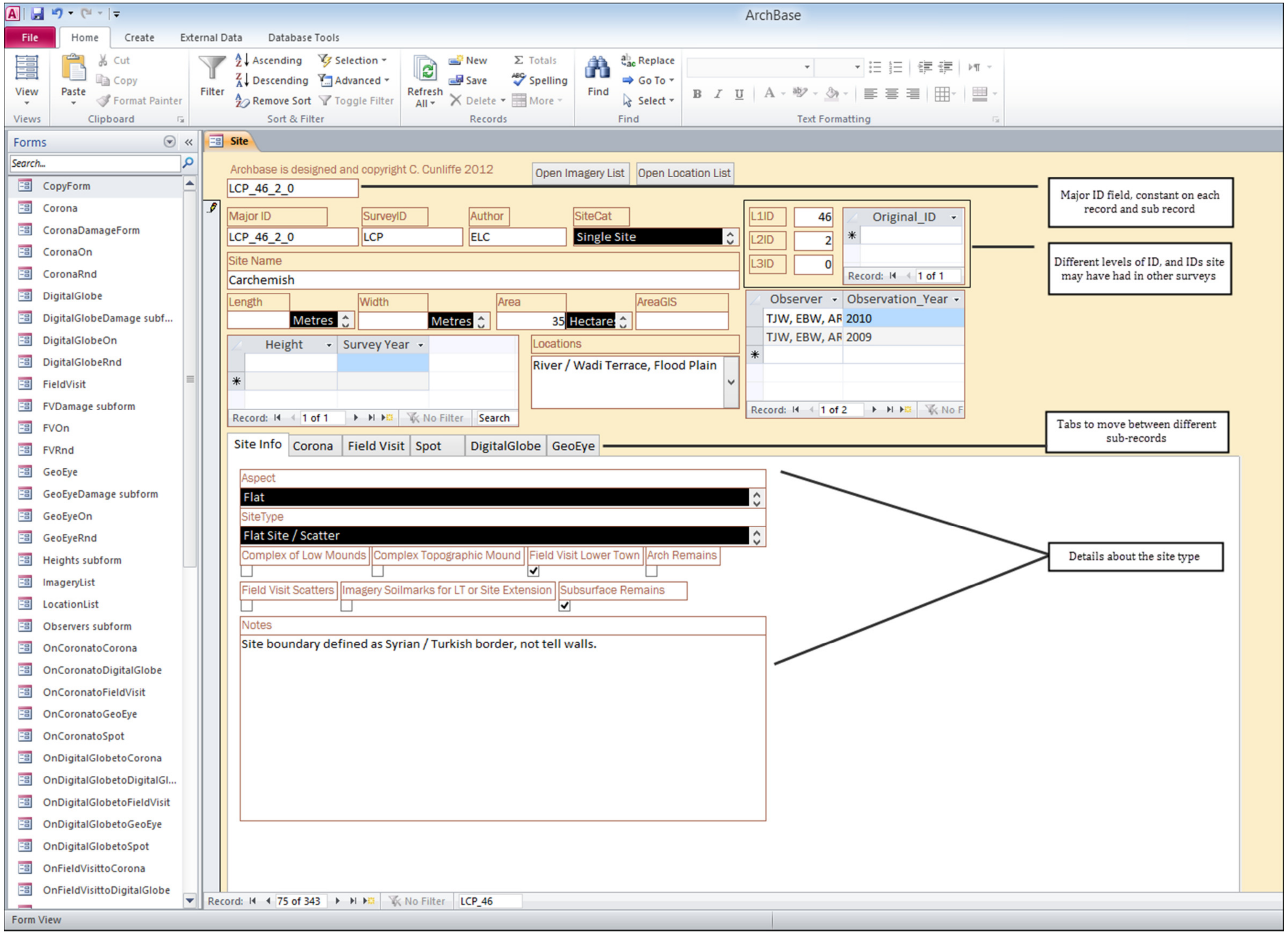

FIGURE 4-1: SCREEN CAPTURE OF THE SITE INFORMATION TAB FROM THE DATABASE

Many of the following criteria have been loosely distilled from those used by the Fragile Crescent Project Database definitions. They have been collated according to characteristics which may affect damage impacts – height, material, and density. Site types have been simplified to the following:

- Tell – mounded unit of greater area and height than Tell (low)
- Tell (Low) – mounded unit, usually 5m or less in height, and 1ha or less in area
- Walls - In-situ construction remains i.e. Walls, aligned blocks etc.
- Flat site / scatter – site with no height visible during field visit / Flat Concentration of artefactual material dispersed across the surface associated with a site
- Irregular structures / enclosures – aligned walls which form enclosures that do not appear to form houses but do form distinct units.
- Buildings – the remains of several buildings could be identified.
- Tombs / Cairns
- Field systems
- Multiple – some amalgamated sites could not be further subdivided as not enough information was available – for example it was known that some flat sites contained tombs, but their location within the site was unknown so subdivision was not possible.

A site consisting of a complex of low mounds will be marked as 'Site Type: low tell', so it is compared to other low tells, and will be ticked as a complex of low mounds, enabling it to be compared to all other complexes of low mounds. Low tells are distinguished from flat sites with subsurface remains because even though they may both consist of several metres of settlement deposits, a site with height is more likely to be damaged by roads, bulldozing, or other threats which physically alter the landscape.

The situation of sites (called the Aspect in the database) were recorded in order to examine whether the aspect has any effect on the damage sites sustain. They were determined from field visit notes (when it was recorded):

- Flat
- Hill / hilltop
- Rolling
- Slope

Although there is a great degree of overlap between them, the site visits were taken as the guide. Most data was collected by Professor Wilkinson and his students, minimising the operator differences inherent in the data collection process.

Site locations were determined from imagery and field notes. In the Tell Beydar area sites were located in 8 land types (see Chapter 6.2, p182, visible on Figure 5-1, p171):

- The basalt plateau
- The plateau escarpment
- The plain to the west of the Wadi ʻAwaidj
- The plain to the east of the Wadi ʻAwaidj
- The plain to the north of the plateau
- Wadi flood plains
- River terraces
- Wadi bottoms and banks

As many of these were very small areas containing few sites, they were usually amalgamated for analysis:

- The plateau and its escarpment
- The plains
- Around the Wadi ʻAwaidj and its flood plain.

In the LCP area there were three main land types, which were defined in Chapter 7.1 and visible on Figure 7-1, p300.

- Limestone hills
- Upland plains
- River terraces

Every site record contains a sub-record for the field visit and for each type of imagery the site or site unit appears on (see Figure 4-2 for a screen capture of an imagery record in the database). Where image types overlap (for example, multiple Corona images showing the same site), only one sub-record is created, although the individual imagery dates contributing to the record are all marked on a drop-down list. Therefore each site has a record of the average condition of the site, for example, on Corona.   In addition, a picture of the site has been uploaded onto each imagery record (and photos for the field visit) in the database, creating a benchmark for future work. All images are

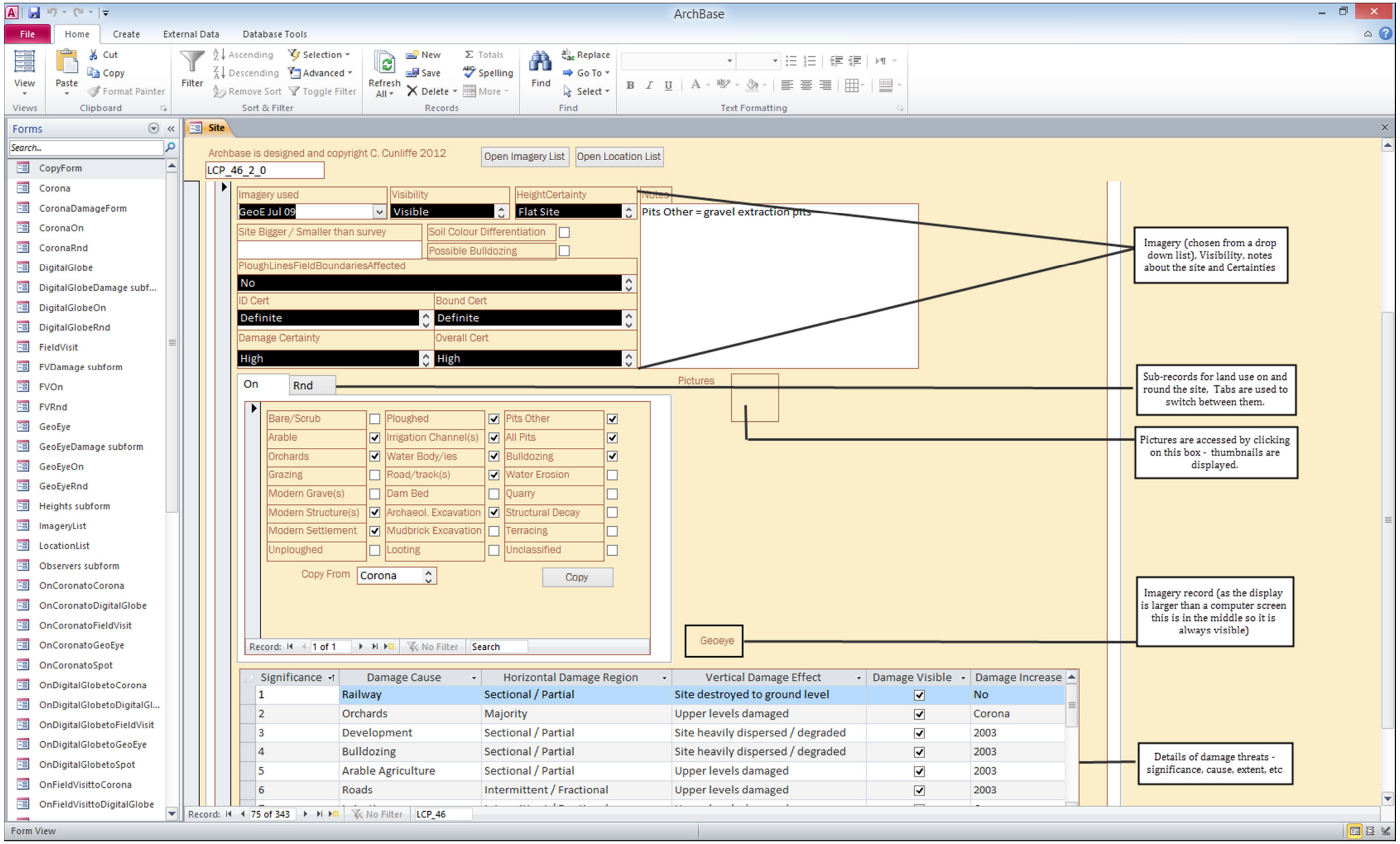

FIGURE 4-2: SCREEN CAPTURE OF THE GEOEYE IMAGERY TAB FROM THE DATABASE

north aligned unless specifically stated otherwise. Due to the difficulties in defining them, site boundaries are rarely included on the images.

Each imagery sub-record lists the visibility of the site and its surroundings on the imagery (defined in Section 4.5.3 – Visibility), the land-use on and around the site (defined in Section 4.5.4 – Land Use and Land Cover), the severity, cause and extent of damage threats to the site (defined in Section 4.5.5 – Type and Extent of Damage), and the certainty of the record (discussed in Section 4.7 – Certainty).

The following sections define and elaborate the more complex terminology used in the database categories, which are used in the analysis of damage. *In later chapters, in order to signify a term with a specific meaning and analysis, the term will be capitalised. If a site is Obscured, for example, this refers to the term Obscured, defined in section 4.5.3 – Visibility. This would mean "*Something is preventing the site from being seen. It is not visible on imagery as it is under a cemetery, modern buildings, or underwater, for example, or the view is blocked by clouds or other weather conditions."

Many of the terms, as will be demonstrated (and discussed in more detail in Appendix E), are ordinal categories. Therefore each term is also given a number. This means that, relatively speaking (and depending on sequence), 2 is 'better' than 3, but not as good as 1. For example, when recording the visibility of sites (Section 4.5.3), a Visible site, equates to the number (1), a Partially Visible site equates to (2), a Barely Visible site is (3), and so on. This is not to say (4) is twice as good / bad as (2) – these are relative categories only. However, this numerical sequencing allows certain statistical tests to be conducted (Appendix E). For ease of reference, each number is written next to the related term in the following definition tables.

4.5.3 – Recording Change: Visibility

Once a site has been identified in the field, and (ideally) a GPS point has been taken, it must be identified on imagery. Given the difficulties of consistently identifying sites on imagery (discussed in Section 4.4, p.126), qualitative assessment categories have been developed. Visibility refers to how visible a site is on imagery, and is defined in Table 4-2. Examples of the different categories of Visibility are given in Appendix B.

TABLE 4-2: DEFINITIONS OF DATABASE FIELDS FOR VISIBILITY OF SITES ON IMAGERY

Visibility	Evidence
Visible (1)	• A site is clearly visible
Partially visible (2)	• The resolution is poor so the site is only partially visible • Part of the site is visible but part is not, either because the resolution of the imagery changes over the site, or some parts of the site are too small to see, such as water channels or rock cut tombs • Part of the site is obscured under a cemetery or modern village, or by clouds.
Barely visible (3)	• Very little of the site is visible, usually because the resolution is too poor to make out more than the location of the site.
Obscured (4)	• Something is preventing the site from being seen. It is not visible on imagery as it is under a cemetery, modern buildings, or underwater, for example, or the view is blocked by clouds or other weather conditions.
Not visible (5)	• The site is not visible on the imagery at all, but nothing obvious (like buildings) is preventing it from being seen.

Visibility is affected by multiple factors. As well as the previously discussed issues of seasonality and environment, the visibility of sites can also be affected by the site location and the site type. Visibility is one of the underlying components which affects the rest of the analysis.

A distinction is made here between sites which are obscured, and sites which are not visible. Sites which are not visible may have been destroyed, whilst the condition of sites which are hidden from view is unknown.

This is not to say that a site which cannot be seen cannot be assessed. For many sites, inferences about the damage can be made depending on the land cover. For example, a site under a town will almost certainly have its upper levels damaged by the establishment of modern infrastructure and building foundations. The upper levels of a site in a field will be ploughed. However, a site which cannot be seen must be assessed according to the principle of least damage (see Section 4.7.3 – Damage Certainty, p161). It is possible that a site in a town is substantially damaged, but as it is usually unknown how far below the surface the site extends, nothing can be said for certain.

In the future it is hoped that some form of spectral index may be developed to assess damage. However, at present sites cannot even be detected with certainty, and the extremely high resolution multi-spectral imagery necessary to develop such indices is prohibitively expensive to many organisations, this approach has not been used here: sites are manually identified. This also allows information to be collected on how land use affects sites.

It is also possible to assess how the visibility changes, which can give insight into the damage to sites. If visibility is considered as an ordinal variable, and counted numerically, then change in visibility can be considered.

Visible = 1, Partially Visible = 2, Barely Visible = 3, Obscured = 4, Not Visible = 5

A site which was "Visible" in 1967 but becomes "Not Visible" by 2010 would then move from 1 to 5, and have a -4 rating. Equally, a site which becomes more visible would have a positive rating. These ratings can then be counted, bearing in mind that as the resolution of imagery improves, sites should become more visible (and therefore gain a positive rating), but as sites become more degraded, they should become less visible (and therefore have negative ratings). Although many factors can 'hide' sites, it is hoped that by considering the area as a whole, a more significant result will be achieved which is less influenced by the environmental constraints of individual sites.

4.5.4 – Recording Change: Land Use and Land Cover

Visibility is clearly affected by the land use on and around a site. According to the Food and Agriculture Organisation

"Land cover is the observed (bio)physical cover on the earth's surface",

whilst

"Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. Definition of land use in this way establishes a direct link between land cover and the actions of people in their environment" (Di Gregorio and Food and Agriculture Organization of the United Nations 2005: Chapter 2).

A land use is a use the land is put to, implying intent. A settlement or an orchard would be a land use, whereas a reservoir bed or a site covered by low scrub would be a land cover. If certain land uses on a site correlate with damage, then they could indicate the likely type and extent of the damage, whilst the land use types around sites could act as a predictor of damage. General assessments have been made of land use and land cover on and around sites.

The land cover and land use types included are not a comprehensive count of all uses on a site, but are tailored to reflect the goal of assessing damage. By counting land use types, it is possible to roughly estimate how “busy” the land was in the 1960s, and how “busy” it is as time passes. Examination could then show if this impacted on the damage sites experienced, or if sites in different areas (of the same survey) were part of different land management strategies and what impact that had. It was also hoped to assess how changes in land management strategies were linked to damage. Many of these categories are the same as the damage types, but are recorded separately to assess if land uses around a site impact the damage it experiences. Although a variety of land categorisations are available (for example see Anderson 1976; Di Gregorio and Food and Agriculture Organization of the United Nations 2005; Homer et al. 2007; United States Geolological Survey 2012), it was decided that many of them are too restrictive, and not all of them adequately reflect the difficulties of using imagery (although some such as Anderson 1976; United States Geolological Survey 2012 were designed with that specifically in mind). However, few reflect the goal of assessing the factors which affect damage: most of them are comprehensive to the point of over-complicating the study. (Some of the categories were also included in the database to further subdivide damage categories and provide greater insight. Some damage categories, such as development types, were combined in order to pool samples for analysis: this allows the data to be interrogated for more information). All non-damaging types were combined into one category (Bare / Low scrub).

Arable land can be classified as ploughed and unploughed, but this information is only available through the field notes or from the highest resolution imagery. The field notes also contain information on whether the site was being grazed at the time. Since this information is not available for all images (or even most) it has not been included in total land-use, since it is not cross-comparable. Small features, such as pits, graves or excavations were not visible on Corona, but they are visible on later imagery or referred to in the field notes. Individually, many of the pit categories are too small to be a statistically valid sample. There are very few categories of pit, and they all have a similar effect, so a category for all the pits (defined in table 3) has been included which can then be statistically analysed. Although small features are rarely visible on SPOT, if they were recorded on the field visits, and were then visible on the

Geoeye, it can be assumed that they were present at the time the SPOT image was taken, and have therefore been recorded as such.

The following categories were recorded (Table 4-3) - those in bold are the types counted in the total land use types. Examples of the different land use categories on imagery, and a brief discussion of their spectral characteristics are in Appendix B.

TABLE 4-3: DEFINITIONS OF DATABASE FIELDS FOR LAND USE / COVER RECORDED ON SITES

<table>
<tr><th>Land Use / Cover</th><th></th></tr>
<tr><td>Bare / Scrub</td><td>Although usually separated in land use categories, here they are combined as these land uses will have little or no impact on the condition of the site.</td></tr>
<tr><td>Arable</td><td>Farming is the most common land cover in the area – the type of crop cover is not relevant, as in many areas 2, or even 3, different crops will be planted each year, so the crop visible on imagery is not reflective of annual practices. The cause of damage is still arable agriculture.</td></tr>
<tr><td>Unploughed</td><td rowspan="2">Sites which are ploughed are visible from the characteristic envelope pattern markings on Corona (For example, Figure 3.10) and plough lines on high resolution imagery. However, an absence of visible plough lines may be a result of the image acquisition conditions (see Section 4.4). Ploughing and its absence are sometimes recorded on field visits notes, but not consistently. Therefore these counts can never act as more than an indication of the increase in mechanised farming. They are a subset of arable land use, and are not counted towards the total land uses.</td></tr>
<tr><td>Ploughed</td></tr>
<tr><td>Orchard(s)</td><td>These are primarily pistachio and olive orchards, which have become increasingly common.</td></tr>
<tr><td>Grazing</td><td>Occasionally noted on field visits, and sometimes visible on imagery. As it is recorded so infrequently, and it is a secondary land use, usually on arable fields, it is not counted towards land use totals.</td></tr>
<tr><td>Modern Grave(s)</td><td>Recorded on field visit notes and visible on higher resolution imagery. Although there is a long history of using sites, particularly tells, for graves and cemeteries, between the 1940s and 1990s this practice increased dramatically, as the land wasn't taxed. The Syrian Government has since declared this practice illegal. Some sites are under cemeteries which are still in use.</td></tr>
<tr><td>Modern Structure(s)</td><td rowspan="2">These development subcategories are separated here in order to distinguish between encroaching urban settlements, and single houses or industrial structures, reflecting greater land use intensity. The cause of damage is Development.</td></tr>
<tr><td>Modern Settlement(s)</td></tr>
</table>

Land Use / Cover	
Irrigation Channel(s)	Changing land uses have led to an increase in irrigation, which often reflects intensifying land use, and can heavily damage sites.
Water Body/ies	Counted if the water body (usually a seasonal wadi) was recorded on the field visit, in which case it was recorded on Corona to represent this information. On later images they are only counted if there is evidence that they still flow. Wadis are visible on Corona as black lines of increased moisture and vegetation. Many channels were recorded as 'relict' or ploughed out in field visits, and rising mechanisation has almost certainly increased that number. It was assumed that most channels were dry unless it could be clearly seen that they still flowed, usually in the form of increased vegetation. Whether a water body was close enough to a site to be counted as 'near' was a slightly subjective judgement based on the imagery. In most cases it was clearly visible along the edges of the site boundary. However, on sites where the boundary was uncertain and possibly more extensive, wadis up to 100m away were included, if there was the possibility the boundary stretched that far. Water bodies are not themselves a damage type: they are the cause of water erosion or burying sites.
Road / track(s)	Roads and tracks on sites cause different levels of damage depending on the type. Roads near sites reflect increasing access to land, and therefore the potential for increased land use and increased damage to sites.
Dam Bed	Actually the dam reservoir bed, this term was a space saving abbreviation. Some sites which were surveyed are now in the bed of the West Hasseke Dam, or on the edge of the survey area and the reservoir bed. Their condition is largely unknown. The damage is classed under Water Erosion due to the limited number of affected sites.
Archaeological Excavation	This is not included as a form of damage, but is a use for land, and opens sites up to faster erosion.
Looter's Holes	These are noted in site visits, and visible on higher resolution imagery, and can cause serious site damage.
Mud brick Excavation	Primarily noted in site visits, and visible on higher resolution imagery.
Pits Other	Pits where the purpose is unknown.
All Pits	A total of modern graves, archaeological excavations, looter's holes, mud brick excavations and Pits (other). As the numbers of individual pits in each category are usually small this is used to assess the damage done by pits generally, and how it relates to the other fields. It does not count

Land Use / Cover	
	towards total land use counts.
Bulldozing	Recorded as a cross check on the damage type: it is not a land use in itself, but usually precedes another land use, such as agriculture.
Water Erosion	See water body/ies. This is a damage effect: the land use is a water body.
Quarry	This tracks the expansion of recent quarrying on or near sites.
Structural Decay	This does not count towards land use totals but reflects field visit notes. It denotes sites which appear to have a ring of soil around them (usually on Corona), as it is likely that these sites are surrounded by eroded soil, distorting their appearance. The damage cause is natural erosion.
Terracing	Usually a result of bulldozing, where terraces were created for agricultural expansion. Ultimately this was not recorded on enough sites so no analysis was done on this category.
Unclassified	On some sites, it is not possible to classify the land cover: it usually applies to low scrub or crop cover.

Many of these land use types also lead to a "post-depositional impact", that is to say, as well as covering the site, they impact on it in some way. These impacts will be considered in individual damage sections, as will other causes of damage.

Note: Damage resulting from a land use which affects the Periphery of a site is recorded as land use **on** a site, although it may also be around it. If the land use is close enough to affect any of the site, then it is also counted as being on the site in the land use total counts (seen in the case study analysis chapters, Sections 6.5 and 8.5).

4.5.5 – Recording Change: Type and Extent of Damage

Identifying Threat Effects on Sites on Imagery

Once identified, sites were entered into a GIS by the Fragile Crescent Project Team, and polygons of corresponding size were created for each site[69]. (For a full discussion of how sites were identified, see Lawrence 2012: it included use of field maps, textual descriptions, maps, and GPS points). These polygons were imported into Google Earth Pro for ease of comparison. However, due to differences in the georectification

[69] Thanks are due to Dan Lawrence and Andrea Ricci, who created many of the LCP shapefiles, and Jason Ur, who created the TBS shapefiles)

of all the images, the polygons do not always line up, making it hard to estimate the extent of the sites over time. Given the issues discussed in recording changes in site extent over time, and the difficulties in determining site extent when it appears larger on imagery than on field visits, it was decided not to use site extent as anything more than a rough guideline to inform the identification (and thus the damage identification) of the extent of sites (see Chapter 2.2 for full discussion). For the LCP survey, multiple GPS points were taken in the field for increased accuracy, and height, soil, colour change, and sherd intensity were all used to determine (where possible) discreet edges to the sites. In some cases the site boundaries were also drawn in the field, or points were imported later into GIS and used to create polygons. However, these GPS-point polygons did not always match the imagery boundaries. It remains unknown whether this is due to rectification / alignment issues, changes in site size, or some other factor relating to light reflection and absorbance on imagery.

For the Fragile Crescent Project, the lack of alignment between sites on imagery and GPS points and shapefiles is less problematic, as it is the relative location of each entity which is of interest, although it can make it hard to compare sites derived from field data with imagery-based topography. However for the purpose of studying damage, it is important to align sites to the imagery correctly in order to establish whether visible damage threats affect a site.

Each site is interpreted independently on each image using the field records for information, and then visually compared to later images. This process allows damage threats affecting sites to be located and recorded. The threats are listed in Chapter 3. For each threat the cause, horizontal extent, vertical extent, stability of the damage type (and thus of the site) and the visibility of each threat on the image were recorded. Examples of the different damage threats on imagery, and a brief summary of their spectral characteristics, are in Appendix B.

Some threats are recorded on the field visits, but are not visible on satellite imagery. This leads to a complication in recording. An important goal of this research is to record and analyse damage to sites, and to assess how useful satellite imagery is for monitoring threats. Therefore it is just as important to record known damage threats which are not visible on imagery as it is to record the threats which are visible. Rather than create multiple database records to deal with this, it was decided to use check boxes on the imagery records to mark whether the threat was visible or not. Each damage threat which is present (known either from imagery analysis or field survey) is entered on each image record: a box is then checked if the threat is visible on the image. This allows all damage to be recorded, and the usefulness of each imagery type can also be assessed. For example, a cemetery is recorded on a site field visit in the Tell Beydar region in 1998. The next available image of the site is a SPOT 2004 image, but the cemetery is not visible due to the low image resolution. However, the cemetery can be seen on a later high resolution Geoeye image from 2010. It can reasonably be assumed that the cemetery was present in 2004, even if it cannot be seen, therefore the cemetery is entered on the SPOT image record, but the Visible check box is not ticked[70].

In some cases, a damage threat may be known from a field visit but it may not be visible on any imagery, either because it was not present at that point in time, or because of the factors which affect image acquisition and interpretation. This presents a problem, as it is the imagery records in the database which are used to analyse the extent of damage to sites, and to monitor change over time. To be included in the analysis, damage threats must be entered on imagery records. When this occurs, it was considered more important to have a full record of damage to sites (the primary objective of this thesis) than a comprehensive assessment of the information gathered from satellite imagery (the secondary aim of this thesis). In these cases, damage threats were entered on the record for the imagery taken most recently after the site visit. To continue the cemetery example, if the cemetery had been recorded on the 1998 field visit, but was not visible on any images, it would be recorded only on the 2004 SPOT image record, but would not be marked as a visible threat. Some threats (namely water erosion) occurred in the past: the effects were noted during site visits, but they were not visibly occurring at the time or on later imagery. In these cases, rather than recording them on the most recent image *after* the field visit, these threats are recorded on the oldest image – Corona – to indicate the antiquity of the threat.

In a sense, some damage threats overlap as damaged areas can be subjected to a secondary use, such as farming or the building of a road. In order to avoid 'double-counting', each damage threat is linked to a particular image, reflecting the order the damage occurred. However, once a site has been bulldozed that damage is recorded on all subsequent database imagery forms: it represents the extensive displacement and / or destruction caused to that section of the site which will continue to have an

[70] This is a separate database field to the Visibility field discussed in Section 4.5.3 – Recording Change: Visibility, which records whether the site is visible, rather than the threat.

effect on the site. In these cases, further damage can occur in the same area from a different cause. Each threat is still recorded separately, avoiding over-counting.

Ultimately, such recording does not alter the total amount of damage sites were experiencing at that point in time, if the record is taken as an indicator of damage at a given point in time, rather than an indicator of what was visible on each image. However, the way the damage is identified should be remembered when examining the damage data tables.

A field visit sub-record has been created for each site, but damage is frequently under-recorded on field survey notes: they cannot be used as a quantitative comparator to earlier or later damage, although they often record damage that is not visible or that is hard to see on imagery. Only recording damage threats which cannot be seen on imagery on the field visit sub-record would add an unnecessarily cumbersome level of complexity to the analysis. However, this method of recording allows the extraction of those threats which were only recorded on field visits from the database. Where this box is ticked, it refers to the cause of the damage, not the visible effect, so visible water erosion, for example, would mean that the wadi was visible, not the that erosion could literally be seen occurring. Continuing this logic, damage may be visible even if the site is not, as long as the site location and boundary is reasonably accurate.

Ordering Damage

Whilst site boundaries are noted, they are not used quantitatively to measure site damage or site loss. Each damage threat is recorded in a subjective order based on a visual assessment of how the damage appears on each image, considering the extent of the threat. The most damaging threat is recorded as the primary damage; the next most damaging is the secondary damage, and so on. The maximum number of threats recorded on a site is ten[71]. The order of the damage is called the Severity of the threat.

Damage Extent: Horizontal and Vertical

Damage affects a site in three dimensions (width, depth and height), as mentioned in Chapter 3.4.2 (p45). For reasons which will be discussed, quantitative assessments of changes in site volume or damaged area could not be made, so qualitative ordinal

[71] Only the entire site of Carchemish had 10 damage threats, if threats to the Outer town and the Tell were counted together, which they were not in the analysis.

categories were developed which could be analysed using non-parametric statistical methods (discussed in Section 4.8.5 – Statistical Analysis Methods and Error Checking). Damage is therefore defined according to both the horizontal extent, and the vertical extent, which covers both depth and height (Table 4-4 and Table 4-5). Examples of each of these from the imagery are given in Appendix B.

The most obvious dimension is the Horizontal dimension. Damage extends across a site, but as discussed, it is not possible to calculate the precise extent of damage across a site without a focused site visit, often supported by imagery interpretation. Even then, site boundaries can be somewhat subjective, as demonstrated by the work of Philip et al. (2012), and discussed more fully in Chapter 2.2. It had been hoped to assess changes in site area across different images, but as site boundaries changed on each image, no consistent comparisons were possible. Instead,Table 4-4 (following page) gives the definitions for the qualitative ordinal categories of horizontal damage extents.

Sites are not completely flat entities: damage also affects the vertical depth of the site. Measures such as the Percentage Area Loss used in the MARS survey (Darvill and Fulton 1998) did not take this into account as depth could not be determined in the field visits conducted. In order to be fully quantified, a percentage loss including the site depth requires the total volume of the site, which cannot be known without fully excavating (and thus destroying) the site.

The ‘top down’ view given by imagery cannot easily be used to calculate the vertical depth of the site which has been affected without excavating to determine the site depth. Some archaeologists have attempted to calculate volume, taking the size and height of sites from Digital Elevation Models (DEMs) and the level of shadows cast by tells, but even this cannot give the depth below the present-day ground surface (Altaweel 2005; Menze and Ur 2012). However, it is possible to make relative assessments of the extent affected by each damage threat across a site as a proportion of the extent of the site recorded during field visits. It is also possible to estimate the relative depth of the site affected, based on what is known of the type of damage each threat causes and the depth of the site as recorded in field.

TABLE 4-4: DEFINITIONS OF DATABASE FIELDS FOR HORIZONTAL DAMAGE EXTENTS[72]

Horizontal Damage Extent	Evidence
None / undamaged (0)	• No damage is visible on the site. * Given the time span over which the sites have existed, and the natural decay processes which affect them, this has not actually been applied to any sites, as per Chapter 3.5.21
Unknown (1)	• The field records for the site are missing, or the land cover on the site is not visible, so that the state of the site at the time of the visit is unknown. If no obvious damage is visible on a site, given the decay processes affecting them, damage is usually marked as Unknown, rather than none, as it is unlikely there is no damage. Natural taphonomic processes will always have affected a site, so "No damage" would be a misnomer. This therefore ranks more highly than None[71].
Peripheral (2)	• The damage is around the edge of the site, and may be affecting the edges of the site, or may represent a threat which puts the site at risk, but is not currently affecting the site, such as an expanding quarry on the edge of the site. If damage extends on to the site, such as an orchard around and on the site, it is recorded as being on the site, rather than around it as well.
Intermittent / Fractional (3)	• A very small part of the site is affected, or the amount of damage being done is very small, such as a hole dug for looting.
Sectional / Partial (4)	• A large part of the site is damaged If the site can be split into clear sections, such as an upper and lower site, or areas of different date, that section (usually as defined by the field team) is affected.
Majority / Extensive (5)	• Most of the site is affected except a small section.
Total / Wholesale (6)	• The entirety of the site is affected, or the site is affected by wholesale damage.

To support the interpretation of damage, and vertical extent affected, for each site, a subjective assessment was made of whether any height appeared to remain, and this was recorded in the following categories:

- Certain
- Uncertain

[72] The numbers in brackets are because this methodology was also developed to create a method for assessing and ranking sites to determine the most damaged site in any given area. This requires Unknown damage to sites to be included as a multiplier (hence the value of 1). However, this work was outside the scope of this thesis, although the values are used in Chapter 9 as part of a damage calculation.

- Flat Site
- Not visible.

Although simplistic, it was hoped this classification could be used to add to the certainty of the results (defined in Section 4.7). If height was recorded during the field visits, or height was visible on later images, it was assumed the site had height on all prior imagery. If height was recorded during the field visit, but was not visible on later imagery, which was the case for some small low mounds, they were classed according to their state during the field visit. For example, a site recorded as a low mound during a field visit, but which later appeared flat would be recorded as a 'low mound' on all records. The height would be recorded as *Certain* on the field visit, but *Uncertain* or even *Flat* on later records. Sites which may have been flattened become easy to identify: they are recorded as low mounds with Uncertain height.

Detecting height is difficult, but not impossible. On prominent mounded sites, the height is clear from the pattern of light and shadow. On the highest resolution imagery, where plough lines are visible, height can also be inferred from their pattern. All things being equal, a farmer will plough his field in the fastest way possible: straight lines. If the plough deviates to curve around a site, it can be assumed that the site still has some height remaining which makes it harder to plough (for example Chapter 6.3.3, and Figure 6-5 and Figure 6-6, p191). Disturbed plough lines can also often be used to indicate the presence of sub-surface remains.

Building on this, the vertical damage extent category estimates the affected depth of the different damage threats. This is estimated from the analysis of each damage threat conducted in Chapter 3 combined with what is known about the site. For example, based on known technology levels, ploughing depths can be estimated with reasonable accuracy, and in some cases site depths are known from the surveys, or can be inferred from the geographic region (soils are very thin in the limestone hills, and flat sites are rarely more than 1 metre or 2 deep. Therefore farming damages the upper levels of a site, unless the site is particularly shallow. Other vertical damage depths are estimated in a similar fashion. Given the approximate nature of these estimates, Damage Certainties are applied to all data collected to reflect the accuracy of the information the estimates are based on (discussed in Section 4.7.3, p161).

It is particularly important to avoid declaring a site to be completely destroyed by a destructive damage threat, such as bulldozing. As demonstrated in Chapter 3, a great many threats do not disturb sub-surface deposits, therefore the categories attempt to account for the possibility of changing ground levels and potentially unknown subsurface deposits. Given the many difficulties discussed in estimating the depth of site damage from satellite imagery, it was not possible to use the same categories for vertical damage extent as for horizontal damage extent. Different categories with different definitions were needed, explained in Table 4-5.

The term "Site Buried" is associated with the damage cause "Water Erosion" in the analysis. Whilst this may appear counter-intuitive, the intent is that the water has eroded sediments elsewhere, and it is these which are burying the site when they are deposited. This can lead to occasions where a site is being eroded and damaged in one location, and buried by sedimentation processes in another. In such cases, the cause would be recorded more than once, but with different affected extents.

If only Peripheral damage is known, and the condition of the site is not visible or the threat cannot be established, then an Unknown threat category will also be recorded. The Peripheral damage will be given the higher Severity rank. If the condition of only part of the site is uncertain, then that damage will be recorded, and no Unknown category will be created.   This will instead be reflected in the Certainties (Section 4.7).

It should be noted that in some cases it appears that the sites has sustained no damage other than natural taphonomic processes. In these cases, "No Damage" would be a misnomer given the passage of time, so the damage cause and extent are marked as Unknown. Reflecting the confidence of this assessment the Damage Certainty (Section 4.7.3) will be Medium. This can be seen at LCP 54, for example. The site is clearly visible on higher resolution imagery, and no anthropogenic damage threats are obvious. This distinguishes the site from one which cannot be seen, and thus also has Unknown damage, as this will have a Low Certainty.

TABLE 4-5: DEFINITIONS OF DATABASE FIELDS FOR VERTICAL DAMAGE EXTENTS

Vertical Damage Extent	Evidence
None / Undamaged (0)	• As for horizontal damage extent, and Chapter 3.5.21
Unknown (1)	• As for horizontal damage extent, and Chapter 3.5.21
Site buried (2)	• The site has been buried, perhaps by alluviation, colluviation, or the flood water and associated sediments behind a modern dam.
Pitted (3)	• Pits have been dug in the site, perhaps for looting, or burials. The pits are of varying depth, and do not cover the entire site. This is considered to be a lesser degree of damage than "upper levels damage". If the entire site is pitted, such as a cemetery covering the entire site, this is recorded as "upper levels damaged".
Site slightly dispersed / degraded (4)	• This usually refers to a mound which is gradually degraded by ploughing, or a site which is being dispersed by erosion.
Upper levels damaged (5)	• The upper levels of the site are being damaged, perhaps by ploughing or a small amount of levelling for a track.
Site heavily dispersed / degraded (6)	• The site is heavily eroded, or has been heavily dispersed / degraded by agriculture. This also refers to heavily looted rock cut tombs. Often when the tombs are looted, artefacts which are considered to be of little value, such as pottery, will be left strewn across the landscape outside the tomb. The tombs are heavily degraded by the looting.
Site destroyed to ground level (7)	• The site has been deliberately (rather than through natural processes) destroyed to the current ground level, but there are (or may be) subsurface remains.
Site destroyed (8)	• There is nothing left of the site, even below the ground.

<u>Damage and Site Stability</u>

Not all damage threats are stable – some increase and some decrease, affecting the site. As discussed in Chapter 3, a gravel track may become a tarmac road, or scrubland may be converted to arable fields, for example, with a corresponding increase in the effect on the site. Occasionally damage decreases – houses may be abandoned, for example, meaning damage associated with occupation ceases. This final damage category records whether the site is stable or if damage threats affecting it are changing. The different categories of stability are listed in Table 4-6. Due to the complexities of recording the change, these categories are not ordinal. Damage increase is categorised by date, not by amount of increase.

TABLE 4-6: DEFINITIONS OF DATABASE FIELDS FOR DAMAGE STABILITY

Damage Stability	
No increase visible	• The damage threat is stable. Damage has occurred but it is not getting worse and no further damage is occurring or is expected to occur from that source: a road was built in the past, for example, or the site is under an orchard. (Although roots may grow, for example, this is not visible, and the damage it causes is dependent on site depth, which is usually unknown).
New	• The threat is new: it was not recorded on earlier imagery.
Increasing	• The damage which is occurring / has occurred from a given threat has increased since the previous image. For example a ploughed site has been converted to an orchard: the damage done by agriculture has increased (as the site has been subjected to ploughing and to the boreholes for trees). In these cases the date the damage increase was recorded is specified.
Increase since / between Corona	• The damage threat appears to have worsened since Corona was acquired or even between Corona image acquisitions.
Increase since / between DigitalGlobe 2003 / 2008	• The damage threat appears to have worsened between DigitalGlobe image acquisitions or since DigitalGlobe imagery (2003) was acquired.
Increase since / between field visits	• The damage threat has worsened between field visits (recorded in field visit notes), or since the field visit.
Increase since SPOT 2004	• The damage threat appears to have worsened since SPOT 2004 was acquired.
Increase since 2008	• The damage threat has increased since the 2008 DigitalGlobe imagery was acquired.
Damage lessening	• The damage has lessened (eg a tractor track is no longer in use, or a field is no longer cultivated)
Not visible / Not applicable / Unknown	• It is not possible to determine whether the threat has worsened or lessened.

4.6 – FIELDWORK AND VERIFICATION

Whilst features can be distinguished on imagery, it is not certain that they are archaeological features, or that the visible spectral signature equates to a damage threat. As discussed, there are many factors that affect how sites appear on imagery, and affect their interpretation - confirmation in the field is essential. This is the main reason why only sites which have already been surveyed on the ground have been used: it provides a benchmark against which to assess change over time. Yet these field records did not focus on the damage, and many sites were only recorded in brief visits, lacking the time to do more than collect pottery and complete a brief assessment of the site. It was therefore necessary to conduct further fieldwork to verify how sites and damage which were visible on imagery appeared on the ground, and to use this information to refine the methodology.

I spent three weeks in Syria in July 2010, observing major Syrian sites (primarily World Heritage Sites, Tentative World Heritage Sites and National Heritage Sites), and then working in the lower town of Carchemish and the area around it to map the damage to those sites. Having already remotely examined both the Beydar and Carchemish areas, it was extremely useful to visit them in person. From these visits, I established that the methodology is appropriate, but a level of caution must be maintained. Available satellite imagery was of varying quality and resolution, differing by area. Google Earth-hosted SPOT imagery, for example, appeared much clearer around Tell Beydar than around Carchemish, where most sites were not visible. Around Beydar most sites were visible, and potential new sites were identified (Wilkinson and Cunliffe 2012; Cunliffe in press b).

However, imagery deficiencies became apparent when the sites were visited in person. At the time, only 2004 SPOT imagery was available for the Tell Beydar area (Figure 4-3). The higher resolution Geoeye did not become available until 2011. Tell Beydar is the largest site in the Beydar area, and the only one I visited. Large parts of the architecture on the tell have been reconstructed after extensive excavations: this was not visible on the SPOT imagery. As the reconstruction work began just after the 2004 date given for the imagery, it may not have progressed to a point at which it could be seen. However, if the imagery is in fact from 2006, as I have suggested, then the reconstruction work was quite advanced by then, and the resolution of the imagery was presumably too low to capture it. As can be seen from the later Geoeye image (also Figure 4-3), the excavations and reconstructions are extensive.

The outer defensive walls of Tell Beydar were visible as soil marks on the SPOT imagery, and this made them seem highly degraded. However, as can be seen from Figure 4-4, a substantial amount of the walls remain. This is much clearer on the higher resolution imagery, which is becoming more commonly available. On the tell itself there were a number of relatively recent graves that had not been visible on SPOT imagery. Imagery interpretation must be approached with caution, as whilst large-scale damage is visible, small-scale intrusions such as looters holes, which are still important, may not be.

FIGURE 4-3: VIEW OF TELL BEYDAR ON SPOT IMAGERY AND GEOEYE IMAGERY[73]

(The * marks the approximate location from which Figure 4-4 was taken and the direction.)

[73] SPOT Image, 31 December 2004(?). Geoeye Image, 23 June 2010. Both taken from Google Earth 23 August 2012.

FIGURE 4-4: THE OUTER WALLS OF TELL BEYDAR AND THE DIG HOUSE[74]

Complicating matters further, Figure 4-5 is the view of the walls from the top of the tell, looking outwards over the dig house. The walls are barely visible, even in person.

FIGURE 4-5: VIEW FROM THE TELL OVER THE WALLS, JULY 2010[75]

The building on the right of the photograph is the dig house on top of the walls, as seen in Figure 4.4, but from the other direction.

[74] Photo courtesy of Stvorek

[75] Photo copyright: the author

The extent and importance of different threats could also be assessed in the field. The damage caused by erosion is often underestimated, but appears to be a severe threat. Several tells have been excavated or reconstructed, and left open to the elements. Most authorities on mud-brick construction (Cooke 2010; Hammond 1973; Keable 1996; Walker et al. 2005; Warren et al. 1993) agree that for mud-brick structures to remain stable, they must be roofed: without such protection, structures will inevitably degrade. Best-practice conservation requirements for excavated sites also demand that, at the very least, they be reburied (ICOMOS 1964; 1999). This had not occurred at several of the sites I visited, and both the excavated and newly reconstructed structures were beginning to degrade. Assessments could also be made of threats such as ploughing, terracing, and bulldozing, investigating how the 'real' appearance of damage compared to that visible on imagery.

Fieldwork developed understanding of site appearance in person and on imagery. Work undertaken in Homs (Beck 2004; Galiatsatos 2004) on the spectral signature of sites ascertained which factors of soil composition influenced site appearance on Corona imagery (discussed in Section 4.4 – Identification of Sites on Satellite Imagery). Soil samples were then taken in the LCP area to confirm the Homs results were still applicable. They were analysed on a Munsell chart and a spectroradiometer was used to assess soil reflectance (see Appendix C). Results demonstrated that there was little difference between wet or dry soils on and off sites, whether using the naked eye (Munsell readings) or the spectroradiometer. All soils tested had broadly similar compositions, proving the difficulties in site identification and analysis. Furthermore, this confirmed that automated data analysis would be extremely difficult: many differences would be too slight for an automated program to detect.

Based on the fieldwork, I adapted my data collection methodology to account for the imagery quality, and to make better assessments of the risks facing sites. For example, Certainty categories (detailed in the next section) have been included to account for difficulties in site identification. Other changes included modifications to the damage categorisation terminology to account for the ambiguities in site and damage extents visible on the ground. As a result of these adaptations my methodology is now more robust. The extent to which remote sensing can be taken, and the inferences that can be made before site visits become necessary, are much clearer. I had hoped to undertake further fieldwork to test the refined methodology and to examine additional sites in person, but this was prevented by the conflict in Syria.

4.7 - Certainty

There are significant differences in the amount, type, and quality of information collected and analysed. This is due to the technology available at the time, and the length, number and coverage intensity of the field seasons, as well as the quality and coverage extent of the imagery. All of these affect the degree of accuracy with which surveys can be entered into a GIS and sites can be identified on imagery. GPS points were taken for surveyed sites and boundaries were drawn in the field. However, "selective availability" was still in operation when GPS was used on the Tell Beydar survey: signals were only accurate to within 30m (or in some cases 50m). Systematic cross-checking of the sites at the time showed that with only minor exceptions, sites were accurately positioned within an acceptable margin of error (Wilkinson 2000). However, problems with georectification of the imagery (usually resulting from the use of low resolution Landsat imagery) have meant that not all images are aligned, although the difference is rarely more than a few metres. In the LCP survey, multiple GPS points were taken on many sites: these site boundaries can be used with greater certainty of accuracy.

There are clearly many factors which affect the certainty of the data. In the Fragile Crescent Project (Lawrence 2012: Chapter 3), this is dealt with through recording Certainty fields which denote the precision of the data, and the certainty of interpretation, given the factors affecting them. Certainty is applied to site identification and location (called geographical precision), archaeological site significance, boundary certainty, and an overall certainty which combines the other categories. This study has dispensed with certainty of archaeological significance, as only field-surveyed sites are included. Instead, the concept of damage certainty is introduced.

4.7.1 - Identification Certainty (Geographical Precision)

In the FCP, "Geographical precision refers to the data available to the person inputting any particular site and the impact this has on the likelihood that the polygon or point which they have drawn is correctly located" (Lawrence 2012: 53) (i.e., it is based on all available information, and assesses the quality of that information). Examples of difficulties can include: GPS error, imagery distortion which could not be entirely corrected for during georectification, and disparities in survey data. In the FCP, sites which have been visited usually have one or several GPS points, giving an accurate on-the-ground position in the WGS datum grid covering the earth. Other sites have only been identified on imagery and have yet to be confirmed as archaeological. This study assesses confirmed archaeological sites with GPS points, but the information about them is derived from imagery which may not be accurately aligned to the WGS datum grid. Some sites may appear on imagery to be several metres away from their GPS location. The extent to which the site is correctly located on imagery will affect what damage is identified. The following table defines criteria for the different levels of certainty: as the aim is to correctly locate sites on imagery, rather than on the ground, the criteria are slightly different to those used by the FCP.

TABLE 4-7: DEFINITIONS OF IDENTIFICATION CERTAINTY / GEOGRAPHICAL PRECISION

ID Certainty / Geographical Precision	Evidence
Definite	• Site was identified in the field AND • GPS point /s were taken AND • Site is clearly Visible on multiple images
High	• Site is clearly Visible on one image OR • Site is at least Barely Visible and has a single GPS point and features on imagery which allow the site to be accurately located (e.g. map features are visible on imagery, or features from other images) OR • Site is Not Visible but there are multiple GPS points and features on imagery which allow the site to be accurately located (e.g. map features are visible on imagery, or features from other images) • AND Sites are accurately drawn on a well rectified topographic map
Medium	• Site is Not Visible on the particular image but the site location is identifiable from other images AND • Single GPS point and features on imagery which allow the site to be accurately located (e.g. map features are visible on imagery, or features from other images), even if site itself is not visible • AND there is a rectified general sites map based on a topographic map
Low	• General sites sketch map only, nothing at single GPS point • General sites map with insufficient detail to rectify to acceptable levels of accuracy
Negligible	• Text description only, nothing to indicate location of site, no identifying features are visible on imagery.

4.7.2 - Boundary Certainty

In the FCP,

> *"levels of confidence in size and shape were recorded as levels of 'boundary certainty'. The term 'certainty' is used in this case to reflect the concern with the quality of the data available, rather than the type of data as was the case with geographical precision, and includes the possibility of integrating multiple data sources. Tracing features from maps and imagery is a subjective process of interpretation… For the surveyed sites, boundary certainty therefore represents the level of confidence of the interpreter that the GIS polygon drawn accurately reflects the shape and size of the surveyed site or feature"* (Lawrence 2012: 57 - 58).

This definition has been re-interpreted to account for the complexities of aligning site boundaries identified during surveys with site boundaries identified on imagery. (This was explored by Philip et al. (2012) and discussed more fully in Chapter 2.2).

Table 4-8: Definitions of Boundary Certainty

Boundary Certainty	Evidence
Definite	• Multiple GPS points and Topographic Map • Multiple GPS points and GIS outline drawn in the field • Multiple GPS points around outline of simple site shape • AND these align to the site visible on the image
High	• 2 or 3 GPS points and Topographic/Topographic-based map • 2 or 3 GPS points and good quality sketch-map • Clear type site – e.g. Tell • Clear Boundary • Very Similar on multiple images
Medium	• Topographic/Topographic-based map • Good quality sketch-map with dimensions • Fairly Clear Boundary • Fairly Similar on multiple images
Low	• Sketch-map only • Dimensions only • Overall sites map suggests site sizes, no other information • Diffuse boundary • Site is different on images
Negligible	• General area description only • Overall sites map with locations only • Very diffuse boundary • Site very different on different images or not visible

For the sake of completeness, certainties were also recorded on the LCP field visit records, which were more detailed than the TBS records. In this case, boundary certainty refers only to the horizontal extent, as it was not always possible to determine if the site was a low mound, or a flat site on a natural ridge.

4.7.3 - Damage Certainty

Damage certainty relates to the damage threats identified on imagery and represents certainty that damage causes and extents affecting sites have been correctly identified, particularly when bearing in mind the uncertainties of boundary definition and of site visibility. It is informed by the site visit, and comparisons of all available images.

Given the many caveats in using comparative sequential imagery, it is extremely important not to overstate damage. It cannot be said for certain that a site which is not visible has been destroyed without supporting evidence. (Ideally a site visit should occur as many sites in the Near East have substantial subsurface deposits. The outer town around Carchemish is visible as cultural material up to a depth of at least two metres in the modern wells) (Wilkinson and Wilkinson 2010).

The analysis is therefore conducted using the principle of least damage. That is:

If damage is not confirmed, the least possible damage is assumed.

For example, if an orchard has been planted on a flat site, this could have severe consequences for the stratigraphy of the site. However, if it is unknown what proportion of the site remains underground, the vertical damage extent assigned is “Upper Levels Damaged”, even though it is likely that the site is “Heavily Degraded”, which is the next most severe category. This prevents damage from being overstated, providing a more accurate starting point from which to develop tools to protect sites, as everything recorded is definitely present, rather than assumed. Certainty is key, as a low certainty assigned to damage can indicate that the problem may be more severe.

No Negligible category was created for Damage certainty or Overall certainty (which relates to Damage certainty): it would have created an unnecessary level of subdivision.

TABLE 4-9: DEFINITIONS OF DAMAGE CERTAINTY

Damage Certainty	Evidence
Definite	• Site location is High / Definite • Damage confirmed by site visit • Extent of damage is clear • Site boundary certainty is Definite
High	• Site location is High / Definite • Damage mentioned on sketch map is visible • Extent of damage is clear
Medium	• Damage is clear but extent is not • Damage mentioned on sketch map but not visible • Site location is High / Medium • Site is not visible but location is Definite / High
Low	• Site location is uncertain • Site is not visible

4.7.4 - OVERALL CERTAINTY

The final type of certainty, introduced for this analysis, is that of Overall certainty. Given the constraints on the data, and the issues of uncertainty in site visibility, identification, boundaries and damage, this reflects an amalgamated certainty, taking all the caveats of data and imagery into account.

TABLE 4-10: DEFINITIONS OF OVERALL CERTAINTY

Overall Certainty	Evidence
Definite	• All fields are definite
High	• Site location is High / Definite • Boundary certainty is High / medium • Damage certainty is High
Medium	• Site location is High / Medium • Site is not visible but location is Definite / High • Damage certainty is High / Medium
Low	• Site location is uncertain • Site is not visible • Damage certainty is low

4.8 – Data Analysis Methods

In order to better analyse the data collected, it is broken down into categories.

4.8.1 – Analysis by Amalgamated Site Type and by Site Unit

As mentioned briefly in Chapter 2.2, site definition is not a simple process, therefore two forms of analysis have been carried out on the sites. The sites identified in the field are often composed of a range of site types, and are usually grouped into one recorded "site" (such as a high mound and group of lower mounds recorded as one site). This is usually based on notions of 'community', but sometimes on geographical proximity. For example, TBS 63 consists of 2 tells (one with a bench) and a low mound, all in the same small village. In other cases, mounds which were not noticed during an initial site survey are then recorded as separate sites.

Some sites are subdivided into separate parts for survey pottery collection. However, many have no distinguishing physical features which would differentially affect how damage threats affect the site. For example, large flat sites are often subdivided for collection purposes to determine whether occupation on different parts of the site is related to period. Yet as the site is flat, a threat like agriculture could affect all parts of the site equally.

In order to account for the confounding effect site type plays in the damage that sites experience, the sites are categorised in two ways. The first is according to site types: for example a tell and its lower town would count as two separate units, whereas a complex of low mounds would be one site, regardless of the number of mounds, as the lower mounds are similar in terms of form and degradation patterns, so damage threats will affect them in similar ways. In cases where there are no distinguishing physical features to justify the separation of the site into component parts, the site is combined into one site in the database record. So, for example, a previously subdivided flat site with no distinguishing features would be also combined into one site. These are called the *amalgamated site type*s: a new database record is created for each amalgamation, and for each site which is subdivided into component types.

Due to the size and density of tells, damage threats which affect them are extremely unlikely to affect other sites around them in similar ways, even other tells, so all tells are examined as single amalgamated sites, even if the different parts were collected separately. Continuing the earlier example, the two tells and the lower mound at TBS

63 are composed of 2 distinct feature types (2 tells and 1 lower mound): these form three separate units.

If an amalgamated site is composed of a High Certainty site, and a Low Certainty site, then Certainties are combined, and a Medium certainty is assigned (i.e. the middle, or most common certainty). Damage is combined, and recorded extents are a proportion of the entire amalgamated site.

However, to continue with the example of groups of low mounds, many of the mounds are spread out across different fields, and are therefore potentially subject to different effects. One particular concern was that grouping the mounds could therefore mask damage which had occurred to individual parts of the site, for example, if one field was bulldozed and one was not. Furthermore, if all sites were divided into their sub-units and counted as individual units, this would simplify the complexities of defining site extents and site components which were discussed in Chapter 2.2. Each mound / settlement area is therefore also counted as an individual *site unit.* A second analysis has also been carried out on the site units. The first analysis is referred to as the *Amalgamated Site Analysis* or the *Type Overview* (in the data analysis chapters and appendices) and the second as the *Unit Analysis*. Single sites, such as lone tells, are included in both analyses. Whether the site is a sub-unit, an amalgamation, or a single site is recorded in a database field. Even if damage threats are only known on one unit, that damage will be recorded on the amalgamated site record, as will any Unknown threats, so that the amalgamated record contains the details of all the site units which comprise it.

4.8.2 – Analysis by Visibility and Certainty

The first type of analysis is that of the visibility of a site, which is conducted by amalgamated sites and site units. If sites are not visible on any images, in most cases very little can be said. However, if a (known) site is visible on an earlier image and not visible on a later image, but it is ploughed, it may be that the site has been ploughed out, in which case inferences can be made. These assessments would have a low certainty, as localised environmental conditions could also be responsible.

Levels of certainty for the survey area as a whole are also assessed. All generalised statements about damage to sites in a given area should be interpreted in light of the levels of visibility of the sites and the certainty of the results.

4.8.3 – *Analysis by Land Use / Cover*

The final contextual analysis is the extent and increase in types of land use / land cover around sites. These are compared to site types and locations to see how these affect the sites' locale. This provides a framework of changing landscape utilisation in which to understand the damage sites are undergoing and the key factors affecting it.

4.8.4 – *Analysis by Damage Type*

Damage is analysed in multiple ways. Each case study is prefaced by a contextual review, which provides information essential to the analysis and interpretation of the damage. This information is in Chapter 5 for the Tell Beydar area and Chapter 7 for the Land of Carchemish survey information. The context is followed by the analysis of damage to sites in each survey area in Chapters 6 and 8.

General trends are considered first, such as damage by site type, damage in the different areas within each study region, and damage extent. The second part of each analysis looks at the damage sources, their general extent and prevalence, and how they affect sites, as well as any potential contributing factors, such as site location or site type. Within each larger case study, certain aspects are examined in more detail: these localised case studies highlight the different types of damage experienced in each area and how it affects specific sites. This is then summarised into key findings for each area, along with a final analysis combining all the data.

4.8.5 – *Statistical Analysis Methods and Error Checking*

In order to conduct the actual analysis, the data is exported from the Access database into Excel spreadsheets, and put through a series of error checking routines to ensure data consistency (Appendix D). The data is then reformatted and imported into SPSS (versions 13 and 20) for analysis.

In many cases the sample sizes are too small for statistical methods to be applied, and only general trends can be suggested, but some statistical tests were possible, and the results have been given where this is the case. Key tables and graphs are included in the Chapters, but the majority are displayed in the Appendices.

Much of the data collected could not be discreetly measured (reasons why are discussed in Section 4.5 - Recording Change), preventing the use of more traditional statistical analyses. However, it can be measured in ranked categories (called ordinal data). Ordinal data is data where, although it can be ordered, "*the amount of difference between the categories is not available*." (Fielding and Gilbert 2006: 15). It can be analysed using a branch of statistics called nonparametric statistics which allow tests on data which does not meet the requirements for more stringent testing, like categorical data.

Three main statistical tests were used to analyse the data. These were the Wilcoxon Signed Rank test, the Mann-Whitney-U test, and the Kruskal-Wallis test. (More information about nonparametric statistics and full details of each test can be found in Appendix E, along with the assumptions underlying the tests, and a cautionary note about the validity of the results).

The Wilcoxon signed rank test can indicate if two related samples differ, testing the assumption that there is no difference in the median value of the population. In this study, it is used to test differences in the total land uses counted on and around sites on the different sets of imagery. The test is also conducted on the total land use counts for each imagery type excluding wadis. Finally it is used to compare changes in visibility over time, for example whether sites were more visible on Corona compared to Geoeye in the different areas on each survey.

The Mann-Whitney-U test is similar to the Wilcoxon Signed Rank test, but can be used when groups are not related. In this study it is used to test whether visibility is different for different site types, specifically whether low tells are more visible than tells in the Beydar area on each imagery type. It also tests total land use counts on and around sites in different areas on each set of imagery. In Tell Beydar, for example, it tests whether the total land use around sites on plains is different to the total land use around sites elsewhere, and whether total land use on and around sites on wadi bottoms, banks and flood plains compared to elsewhere. A similar analysis is conducted around Carchemish comparing land use on and around sites on the limestone hills to those elsewhere, those on the plains to those elsewhere, and those on the river terraces to those elsewhere. In the TBS analysis, it also tests whether lower towns experienced more horizontal or vertical damage on each image than low mounds. In the LCP analysis, vertical and horizontal damage is compared on lower towns and flat sites.

Lastly, the Kruskal-Wallis test of mean rank tests the null hypothesis that multiple independent groups / populations (at least 3) have identical distributions against the alternative hypothesis that at least two of the samples differ only with respect to location (median), if at all. It is used in this study to test whether visibility of sites is different on different types of imagery.

It should be noted that in some cases, data are uncertain, such as boundaries (see the discussion of site extent in Chapter 2.2). Size affects how many damage threats a site can experience, but it is not always possible to estimate it for certain. This could affect subsequent quantitative analysis if the estimate was wrong. Site boundaries are assumed to be how they were drawn in the field visits, even if they appear larger on imagery, giving an element of standardisation to the data. Any statistical results are therefore at worst under-representing the damage, but never over-stating it.

4.9 - Limitations and Constraints of Data

This work is of course subject to numerous constraints and limitations, not least of which is the method of study chosen: satellite imagery. This is both a benefit, in that large areas can be surveyed quickly and cheaply, and a hindrance, in that imagery is subject to interpretation and some degree of ground verification is essential for correct understanding. Furthermore, the archaeological resource cannot easily be measured even on the ground, as a good deal remains below the surface, and this is particularly hard to monitor using imagery.

It is also acknowledged that the definitions used here exclude some forms of archaeological material, such as botanical remains, and that the study is limited to only certain types of archaeological forms, and focuses only on broad trends in damage. Off-site features are also excluded, although they form a fundamental part of the palimpsest of human occupation.

The terms and methods of analysis developed were created with this limitation in mind, and would be equally applicable to other feature types if the study were extended in the future. There are also inconsistencies in the manner of data recording within the two case study surveys, meaning they are not directly comparable, a fact that is discussed by Lawrence (2012). The Tell Beydar survey, for example, was conducted when field GIS and GPS were just becoming available. The field seasons totalled just under six weeks over two years, and whilst a third season was planned, it was not possible to carry it out. The Land of Carchemish Project had four field seasons, conducted over several months, carried out with much more advanced field GIS and more accurate GPS. Again, further work was planned, but could not be conducted due to the internal situation in Syria. Both surveys attempted low-intensity full coverage to recover the basic settlement pattern, combined with imagery study, and supported by sample transect surveys and fieldwalking to identify as many sites and off-site features as possible. The higher resolution imagery available and improved analysis techniques available to the LCP survey also resulted in the identification of more sites. It is therefore not possible to directly compare the field derived data. Due to the constraints placed on the Tell Beydar Survey, the LCP data is more comprehensive and the data is more consistent, and comparative Tell Beydar data is not always available.

Professor Tony Wilkinson oversaw both surveys, so substantial additional data was available beyond the published record, including survey notes, and the knowledge base. The LCP survey publications currently consist of field season summaries (awaiting further fieldwork), therefore access to the data is particularly important.

This study has worked with the material available at the time (2012), knowing that there are omissions within that data. Both surveys were cut short due to changing conditions within Syria, and further field seasons were planned in both cases but have not been carried out. Several potential new sites have been identified on imagery, as well as possible extensions to several others (Wilkinson and Cunliffe 2012; Wilkinson et al. 2012). As they have not been confirmed as definite archaeological material, they have not been included in this study. As well as an evaluation of new methodology, this work provides a benchmark of the condition of the archaeological resource at the time of study. The archaeological resource is continually evolving as new sites are discovered, and these could be evaluated if this work was repeated in the future.

4.10 - Concluding Remarks

The methodology described here will enable the analysis of site damage using comparative imagery informed by field visits. Satellite imagery is an increasingly useful tool in archaeology, and as higher resolution imagery becomes cheaper more applications can be developed. As it is not feasible to visit large numbers of sites on the ground, it is hoped that the results from this approach can be generalised to similar areas with similar sites across the Near East.

In the following chapters this method will be applied to two case studies in Syria. The Tell Beydar area is a largely agricultural area with a low population density, few villages, and increasingly intensive irrigation from the nearby West Hasseke Dam, which is described in the following Chapter 5. This provides the historical and environmental context for the analysis of site damage in that area in Chapter 6.

Chapter 7 describes the area around Carchemish, near the Turkish border. It is also an agricultural area with localised irrigation, but without the major irrigation networks resulting from the dam. Large areas also contain more marginal soils: these are separated from the Euphrates, Sajur and other rivers by high bluffs, and so do not benefit from even the localised river-based irrigation. In the past, and still today, these areas were less intensively occupied. Building on this foundation, Chapter 8 contains the results of the analysis of damage to sites in the second case study region.

Both areas have a similar number of surveyed sites from a similar range of periods: site damage can be recorded, statistically analysed and compared using the methodology outlined here. Once each area has been analysed separately, the two areas will be compared, and commonalities in how damage affects sites can be identified to apply to the wider region of the Near East.